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GEOLOGICAL SURVEY OF MICHIGAN

LOWER PENINSULA

1896-1900

VOL. VII

PART I. MONROE COUNTY, W. H. SHERZER
PART II. HURON COUNTY, A. C. LANE
PART III. SANILAC COUNTY, C. H. GORDON

GEOLOGICAL SURVEY OF MICHIGAN
ALFRED C. LANE, STATE GEOLOGIST

VOL. VII
PART I

GEOLOGICAL REPORT

ON

100810

MONROE COUNTY
MICHIGAN

BY

W. H. SHERZER

ACCOMPANIED BY SEVENTEEN PLATES AND EIGHT FIGURES INCLUDING
THREE COLORED MAPS

PUBLISHED BY AUTHORITY OF THE LAWS OF
MICHIGAN
UNDER THE DIRECTION OF
THE BOARD OF GEOLOGICAL SURVEY

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ERRATA.

Page 2, line 8, for *Eutænia sertalis* read *Eutænia sirtalis*.

Page 2, line 8, for Trepidonotus read Tropidonotus.

Page 2, line 10, for Oppibolus read Ophibolus.

Page 2, line 11, the latest authorities change *Caudisona catenata* to *Sistrurus catenatus* or *Sistrurus tergeminus*.

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Office of the State Geological Survey,
Lansing, Mich., June 21, 1900.

To the Honorable, the Board of Geological Survey of Michigan:

Hon. Hazen S. Pingree, *President.*
Hon. Perry F. Powers.
Hon. Jason E. Hammond, *Secretary.*

Gentlemen—Herewith I transmit the Report, maps and illustrations of the report on Monroe county prepared by Prof. W. H. Sherzer, the issue of which, as Part I of Vol. VII, you have authorized. Five hundred copies as you have voted are issued separately, while the remainder of the edition is reserved to be bound up with the remaining parts, upon which the printer is now at work. This and the following report upon Huron county are of rather exceptional size, because the two counties themselves are of exceptional geological interest. They have more than usually numerous rock exposures, and taken together, they cover pretty fairly the whole variety of rocks and surface conditions in the Lower Peninsula. Thus dwellers in the other counties thereof will find much information which they can apply to their own homes.

Some of the valuable results of Prof. Sherzer's work are: the description of the considerable thickness and extent of the Sylvania glass-sand, a work of great value to a State so exceptionally well situated for glass manufacture as Michigan; the description of the deposits of high grade limestone and strontianite, both of which may be important factors in beet-sugar manufacture, while the former is also in great demand for the manufacture of soda ash; and the determination of the limited extent and economic value of the oil and gas. The professional geologist will appreciate the light thrown on the Helderberg question, and on the detailed history of the Great Lakes.

With great respect, I am your obedient servant.

ALFRED C. LANE,
State Geologist.

TABLE OF CONTENTS.

CHAPTER I.

GEOGRAPHICAL AND HISTORICAL INTRODUCTION.

A. Geographical: Page.
- § 1. Location 1
- § 2. Railroads 1
- § 3. Proposed lines 2
- § 4. Miscellaneous data 3

B. Historical:
- § 5. Early boundaries 3
- § 6. Indian occupation 5
- § 7. Early settlements 6
- § 8. War of 1812 6
- § 9. Growth of population 7
- § 10. Southern boundary 7

C. Geological Work in the County:
- § 11. Previous work 9
- § 12. Houghton survey 9
- § 13. Winchell survey 12
- § 14. Rominger survey 14
- § 15. Work of present survey 15
- § 16. Acknowledgments 16

CHAPTER II.

DEVONIAN AND QUATERNARY.

A. Quaternary Deposits:
- § 1. Thickness 18
- § 2. General nature 19
- § 3. Boulders 20
- § 4. Post-glacial deposits 24

B. Devonian Formations.—St. Clair (Genesee) Shales:
- § 5. General arrangement of Devonian formations 25
- § 6. Name 25
- § 7. General data 25
- § 8. Thickness 26
- § 9. Lithological character 26
- § 10. Geological position 27
- § 11. Lithological history 29

C. Traverse (Hamilton) Group:
- § 12. Name and geological position 31
- § 13. General data 31
- § 14. Thickness 32
- § 15. Lithological characters 32
- § 16. Lithological history 35

D. Dundee Limestone: Page.
§ 17. Name and geological position 35
§ 18. General data 37
§ 19. Drift covering 38
§ 20. Thickness 38
§ 21. Lithological characters 38
§ 22. Lithological history 40

CHAPTER III.

SULURIAN FORMATIONS.

A. Monroe Beds:
§ 1. Name and geological position 43
§ 2. General data 44
§ 3. Thickness 45
§ 4. Lithological characters 46
§ 5. Lithological history 48
Description of Special Beds:
§ 6. Sylvania sandstone 53
§ 7. Oölitic beds 60
B. Beds reached by Borings:
§ 8. Deep well records 66
§ 9. Interpretation of records 73

CHAPTER IV.

QUARRIES.

A. Dundee Formation:
§ 1. Macon quarry 75
§ 2. Dundee quarry 77
§ 3. Petersburg excavations 78
B. Monroe Beds:
a. Quarries above the Sylvania sandstone:
§ 4. Woolmith quarries 78
§ 5. Raisinville quarries 82
§ 6. Ida quarries 85
§ 7. Lulu quarry 87
§ 8. Little Sink quarry 88
§ 9. Ottawa Lake quarries 89
b. Quarries below the Sylvania sandstone:
§ 10. Newport quarries 92
§ 11. Frenchtown quarries 93
§ 12. Monroe quarries 95
§ 13. La Salle quarries 97
§ 14. Bedford quarries 98
§ 15. Whiteford quarries 100

CHAPTER V.

PHYSICAL GEOGRAPHY.

§ 1. Climate 101
§ 2. General configuration of the county 105
§ 3. Elevations within the county 106
a. U. S. survey levels 106
b. Railroad levels 107
c. Elevated beach levels 109
d. Aneroid levels 109
§ 4. Surface drainage 109
§ 5. Underground drainage 114
§ 6. Diagonal features 118

CHAPTER VI.

THE GLACIAL EPOCH IN SOUTHEASTERN MICHIGAN.

A. Rock Surface Topography: Page.
- § 1. Introduction 121
- § 2. Traverse valley 122
- § 3. Dundee valley 122
- § 4. Sylvania valley 123
- § 5. Erie trough 124

B. The Ice Invasion:
- § 6. The early ice sheets 124
- § 7. The Wisconsin ice sheet 126
- § 8. Rock scorings 128

C. Lacustrine stages:
- § 9. Introduction 132
- § 10. Lake Maumee 133
  - a. Van Wert stage 133
  - b. Leipsic stage 135
- § 11. Lake Whittlesey 135
- § 12. Arkona beach 138
- § 13. Lake Warren 140
  - a. Forest stage 140
  - b. Grassmere stage 141
- § 14. Lake Erie 144
- § 15. Recent submergence 145

D. Post-glacial warping:
- § 16. Recent production of stony ridge 147

CHAPTER VII.

SOILS AND SUBSOILS.

A. Nature, Origin and Varieties:
- § 1. Preglacial soils 149
- § 2. Glacial subsoils 151
- § 3. Post-glacial soils 153
  - a. Sand and gravel 153
  - b. Clay 154
  - c. Loam 155
  - d. Silt 155
  - e. Muck 156

B. Relation of Soils to Vegetation:
- § 4. Fertility 157
- § 5. Fruit culture 160
- § 6. Farm products 161
- § 7. Forest growth 164

C. Amelioration of Soils:
- § 8. Importance of subject 165
- § 9. Natural amelioration 166
  - a. Inorganic agencies 166
  - b. Organic agencies 168
- § 10. Artificial amelioration 171

CHAPTER VIII.

ECONOMIC PRODUCTS.

- § 1. Building materials 174
- § 2. Quick lime 175
- § 3. Soda ash limestone 177
- § 4. Beet sugar limestone 178

Page.
§ 5. Cement materials 180
§ 6. Road metal 183
§ 7. Glass sand rock 186
§ 8. Brick and tile 187
§ 9. Natural gas and oil 190
§ 10. Artesian water and mineral springs 194
§ 11. Marl 200
§ 12. Salt 201

CHAPTER IX.

MINERALS OF MONROE COUNTY.

A. Carbonates.

§ 1. Introduction 203
§ 2. Calcite 203
§ 3. Aragonite 204
§ 4. [illegible] 205
§ 5. Dolomite 206
§ 6. Strontianite 206

B. Sulphates.

§ 7. Celestite 206
§ 8. Gypsum 208
§ 9. Anhydrite 209
§ 10. Epsomite 210

C. Chlorides.

§ 11. Halite 211

D. Sulphur and Sulphides.

§ 12. Sulphur 212
§ 13. Pyrite and marcasite 213

E. Oxides.

§ 14. Bog iron ore 214
§ 15. Crystallized quartz 215
§ 16. [illegible] 216

F. Phosphates.

§ 17. [illegible] 217

G. Hydrocarbons.

§ 18. Asphaltum 217
§ 19. [illegible] 218

CHAPTER X.

[illegible] OF MONROE COUNTY.

§ [illegible] .... [illegible]
§ [illegible] .... [illegible]
§ [illegible] .... [illegible]
§ [illegible] .... [illegible]

LIST OF ILLUSTRATIONS.

PLATES.

Page.
I. Map of Paleozoic Geology .... faces
II. South wall of the Woolmith quarry, showing massive building blocks of the silicious dolomite .... p. 80
III. View of the Cummins quarry, locally known as the "Little Sink." Observe the scanty soil and stunted forest growth .... p. 88
IV. Quarry floor, west wall and crusher of the Monroe Stone Company p. 96
V. Section of the Monroe well (from Vol. V.) .... p. 100
VI. Cross sections along line of railroads .... p. 105
VII. Map of Surface Geology .... p. 112
VIII. View of the River Raisin at Monroe, showing the typical beds of dolomite .... p. 113
IX. Rock opening through which the water of the "Big Sink" escapes. View looking into the bottom of a small ravine .... p. 116
X. Bed of Ottawa Lake sink, from the head looking southward. Oct. 15th, 1898 .... p. 118
XI. Sand ridge of lower beach west of Erie, showing typical growth of oak and evergreen. Dec. 4, 1897 .... p. 120
XII. View of Stony Point looking northeastward toward Point aux Peaux. Observe the ice polished and battered condition of the rock in the foreground .... p. 128
XIII. Roadway through one of the Monroe nurseries, showing a typical wave washed flat .... p. 140
XIV. Outcrops of the "Monroe beds" at Point aux Peaux, Lake Erie ...... p. 144
XV. Map, contours showing depth of drift, oil and gas and artesian belts, etc., also indicated .... p. 192
XVI. Site of the "Shawnee Spring" near Monroe. The extensive mound built up by the spring is but faintly shown in the field beyond the picket fence .... p. 198
XVII. Waterlime Fossils, reprinted from Annals N. Y. Acad. Sciences, Vol. V, Pl. V, Ohio Geol. Survey, Second Ann. Report and Vol. VII, Plate I.. 242

FIGURES.

1. Mammoth boulder transported by the ice sheet and dropped east of the site of Ida. Four feet above ground; twenty feet long 21
2. The "Big Sink" doing service as a lake, March 26, 1898........ 115
3. The "Big Sink" under cultivation, Oct. 15, 1898........ 115
4. View of the government canal, near Monroe, opening into Lake Erie.. The view gives one an idea of the inundated "drowned" appearance near their mouths of all streams which empty into Lake Erie........ 146
5. Lotus bed in the marsh near Monroe. The marsh is due to recent submergence by the Lake. Photographed, August, 1890 148
6. View of extensive Cranberry marsh when flooded in the spring. Sec. 24, Summerfield township 157

Page.
7. Gushing well struck upon Otter Creek, Sept., 1899. Residence of Edward Sharkey, 2½ miles southeast of La Salle.................................. 197
8. Great Sulphur spring in the lake marsh near Erie. The figure gives also a view of the inundated margin; cf. Fig. 5.................................. 199

TABLES.

I. Statistical data of Monroe Co., Michigan 4
II. Annual Climatic data, Grape, Monroe Co., Michigan.................................. 102
III. Annual Climatic data, Toledo, Ohio 103
IV. Average Monthly Temperature and Precipitation, 1871-1899.................................. 104
V. Annual Climatic data Toledo, 1860-1869.................................. 104
VI. Altitudes of Railroad stations 108
VII. Glacial striæ in Monroe Co.................................. 131
VIII. Former Lake Beaches in Monroe Co.................................. 143
IX. Percentage Composition of Air Dry Farm Products.................................. 159
X. Bushels of Fruit Produced in 1898 161
XI. Monroe Co. Farm Products for 1898 162
XII. Composition of Limestone found suitable for Beet Sugar Manufacture.. 179
XIII. Composition of American Cement Rocks 181
XIV. Composition of English Portland Cement.................................. 182
XV. Key to the Minerals of Monroe 219

ERRATA.

Page 129, line 9 from bottom, for Chamberlain read Chamberlin.
Page 181, Table XII should be Table XIII.
Page 199, line 4, for Cushino read Cousino.
Page 219, Table XIV should be Table XV.

CHAPTER I.

INTRODUCTION.

A. Geographical.

§ 1. Location.

The county which constitutes the subject of this report occupies the extreme southeastern corner of the lower peninsula of Michigan. To the north are Wayne and Washtenaw counties, to the west Lenawee county; Lucas county of the state of Ohio, forms the southern boundary while the eastern is formed almost entirely by Lake Erie. The county covers about 560 square miles, distributed over fifteen townships between 41° 44′ and 42° 6′, north latitude; and between 83° 11′ and 83° 46′, west longitude.[*]

§ 2. Railroads.

Eight lines of railroads intersect the county in all directions and no portion of it is beyond the sound of their heavily loaded trains. Parallel with the lake shore and back from it from one to five miles, the Michigan Central and Lake Shore traverse the county in a northeast and southwest direction. To the west the Pere Marquette enters from the north, swings to the southwest near Monroe and passes into Ohio about a mile west of the two preceding roads. The Detroit and Lima Northern enters the county from the west, from Dundee turns northeastward, crossing the Pere Marquette at Carleton and enters Wayne county at the northeastern corner of Ash township. Having the same general direction as all of the preceding and the common purpose of centering in Detroit, a branch of the Wabash grazes the northwestern corner of the county.

---

[*] The exact location of points somewhat near the four boundaries of the county, as determined by the government engineers, is as follows:

	Latitude N.	Longitude W.
Gibraltar lighthouse	42° 05′ 25.90″	83° 11′ 14.80″
Turtle Island lighthouse	41° 45′ 08.80″	83° 23′ 28.80″
Monroe lighthouse	41° 53′ 27.70″	83° 19′ 53.20″
Triangulation Station near Dundee	41° 55′ 28.08″	83° 40′ 13.93″

Heading for Toledo, the Ann Arbor gives a nearly complete northwest and southeast section of the county through Milan and Dundee to Alexis junction with the Pere Marquette. Nearly parallel with it the Toledo-Adrian branch of the Lake Shore cuts the extreme southwestern corner of the county. The only east and west road within the limits of Monroe county is the Monroe-Adrian branch of the Lake Shore, passing through Petersburg. These last two branches of the Lake Shore system are of historic interest since they were the first railroads in the northwest. The Toledo-Adrian road was originally built by private enterprise in 1836 and was known as the Erie and Kalamazoo railroad. For about a year the cars were drawn by horses over wooden rails, when the "strap rail" was laid and the first locomotive introduced. The road from Monroe to Adrian was constructed in 1839 by the then infant State of Michigan for the purpose of opening up the interior and was operated by it until 1846, when it was sold to the Michigan Southern Railroad Company.

§ 3. Proposed lines.

During the summer of 1899 the bed for a new road from Toledo to Detroit was in process of construction, lying between the Michigan Central and Lake Erie, to be known as the Detroit and Toledo Shore Line. The grading from Toledo to Monroe is well advanced and will probably be completed within the limits of the county during the coming summer. By closely hugging the shore of the lake and of Detroit River it is claimed that the distance between Detroit and Toledo will be materially lessened. An electric road intended to connect these two cities awaits completion. The grading from Erie to Monroe is practically done, following throughout the greater part of the distance the main highway, and a power house has been constructed in Monroe. The franchises have been secured for an electric road from Ypsilanti to Milan which it is expected will be continued to Adrian, thus crossing Milan township. It is reported to be the intention of the promoters of this road to construct a line from Milan, through Dundee, to Toledo. Still another road, with branches from Ann Arbor and Detroit, is expected to enter the county north of Carleton and to follow the approximate line of the Pere Marquette to Monroe. With such development of steam and electric lines, connected with every farm by means of substantial stone roads; with the private telephone, free rural delivery of mail, and the attendant improvement in educational facilities, the life of the farmer is one to be envied, and the question of keeping the son and daughter upon the farm will be largely settled.

§ 4. Miscellaneous data.

Table I gives an alphabetical list of the townships of the county, their postoffices and some miscellaneous information relating to them, gathered from latest available sources. It shows the population in 1894 to have been 33,181. The city of Monroe is the county seat, having in 1894, a population of 5,613. There are three incorporated villages, namely: Dundee, 1,115; Petersburg, 446; and Milan, 964.

B. Historical.

§ 5. Early boundaries.

Early in the century just closing, "Wayne County" comprised the entire lower peninsula of Michigan, a part of the upper peninsula as well and adjoining portions of Ohio, Indiana and Wisconsin. From this vast tract Monroe county was set off in 1817, by proclamation of Gen. Lewis Cass, then governor of Michigan Territory; the present Wayne county having been established two years earlier. The original proclamation by which the boundaries of the county were first established is here given.

"WHEREAS, It is considered that the public good will be promoted by the erection of a new county in the said Territory;

Therefore, I do, by virtue of tne power and authority in me vested, constitute the whole of that portion of said territory of Michigan which is included within the lines and limits following, that is to say: Beginning at the mouth of the river Huron of Lake Erie, within said territory; thence up the said river in the middle thereof until its intersection with the line between the third and fourth tier of townships south of the "base line," so called; thence due west with the said line until it shall intersect the present Indian boundary line, namely, to the western line of the first range; thence with said line due south to the southern boundary of said territory; thence along the southern boundary thereof, easterly to the southeast corner thereof; thence northerly along the eastern boundary of said territory to a point due east from the place of beginning; thence to the place of beginning; to be and remain henceforward a separate county, to be called the county of Monroe.

* * * * * * * * *

Given under my hand and the great seal of said Territory, at Detroit, this fourteenth day of July, A. D. one thousand eight hundred and seventeen, and in the fortieth year of the Independence of the United States of America.

LEWIS CASS."

An inspection of the present map will show that as thus outlined the county was much larger, upon the north and west particularly. A second proclamation, issued five years later, reduced it to its present limits, but attached to it the county of Lenawee, from which it was separated in 1826.

"The county of Monroe, established by an executive act of July 14, 1817, shall be bounded as follows:

Beginning at the boundary line between the United States and the province of

TABLE I.—*Statistical data of Monroe County, Michigan.*

No.	Township.	Tier south.	Range east	Population, 1894.	Area in acres Supervisors' assessment, 1896.	Acres in farms, 1898.		Number farms, 1898.	Average size of farms in acres.	Postoffices.
						Improved.	Unimproved.			
1	Ash	5	ix	2.039	22.485.99	13.818	3,877	251	70	Carleton. Grafton.
2	Bedford	8 and 9	vii	2.075	25.100.35	15.455	4.153	291	67	Samaria. Temperance, Lambertville.
3	Berlin	5 and 6	ix and x	1.850	22,334.17	7.326	2.387	58	167	South Rockwood. Newport.
4	Dundee	6	vi and vii	3.303	29.828.48	20,000	9.000	665	44	Dundee, Rea.
5	Erie	8 and 9	viii	1.476	18,356.15	11,960	505	153	81	Erie.
6	Exeter	5	viii	1.912	22,811.79	14.975	4,166	266	72	Exeter, Scofield, Maybee.
7	Frenchtown	6 and 7	viii, ix, x	1.958	29.425.23	18.629	3.115	261	83	Brest. Steiner.
8	Ida	7	vii	1.594	23.409.75	14.768	4.122	261	72	Ida. Lulu. Morocco.
9	LaSalle	7	viii and ix	1.333	16.109.55	12.638	2.307	183	82	LaSalle, Yargerville.
10	London	5	vii	1,373	22.596.91	10.777	4,480	201	76	London, Oakville.
11	Milan	5	vi	2,105	22.506.63	12.239	1.510	161	85	Milan, Azalia, Cone.
12	Monroe	6 and 7	viii and ix	6.490	13.271.07	7.328	1,940	116	80	Monroe.-
13	Raisinville	6 and 7	vii and viii	1.775	29.757.34	19.908	3.587	245	96	Strasburg, Raisinville, Grape.
14	Summerfield	6 and 7	vi	2.038	26,193.68	13.669	5.367	223	85	Petersburg.
15	Whiteford	8 and 9	vi	1,860	25,984.80	16,455	4;503	291	72	Whiteford Center, Gert, Ottawa Lake.
	Totals	5 9	vi x	33.181	350,171.89	209.945	55,059	3,626	73	33 offices.

Upper Canada, where the southern boundary of the county of Wayne intersects the same, thence with the said southern boundary, west to the mouth of the river Huron of Lake Erie; thence with the said boundary, keeping the middle of said river, to the line between the townships numbered four and five south of the base line; thence west to the line between the fifth and sixth ranges east of the principal meridian; thence south to the line between the Territory of Michigan and the State of Ohio, thence with the said line to the boundary between the United States and the province of Upper Canada; thence with the said boundary line to the place of beginning. * * *

In testimony whereof I have caused these letters to be made patent, and the great seal of the said Territory to be affixed. Given under my hand at Detroit, this tenth day of September, in the year of our Lord one thousand eight hundred and twenty-two, and of the Independence of the United States the forty-seventh.

LEW. CASS.

§ 6. Indian occupation.

The earliest inhabitant, of whom we have any definite traces in southeastern Michigan, was the so called "Mound Builder." If the Palæolithic man of Europe had any representatives in this region his remains and crude implements are yet to be discovered and identified. The tendency of recent investigations of the Ohio and Mississippi valleys is to destroy more and more, the gap between our historic, eastern Indian and the mound building type of savage who depended more upon the soil for his subsistence and defense. It must be admitted, however, that he was intellectually the superior of the Indians who dispossessed him of his fertile fields and drove him, probably southwestward. He cultivated the soil extensively, wove cloth, burned pottery, manufactured a superior stone implement and worked our copper mines for the red metal. For purposes of burial and sacrifice, and apparently for use as signal stations from which messages could be flashed across the country after approved modern methods, he constructed hemispherical and conical mounds of loose earth. Some very interesting mounds of this character along the St. Clair and Detroit rivers were explored thirty years ago by Henry Gillman, of Detroit, and described in publications of the Smithsonian Institution, the American Association for the Advancement of Science, and those of the Michigan Pioneer Society. At favorably located points fortifications were constructed, sometimes of great magnitude, displaying a surprising degree of military skill and testifying to the patience and industry of these people. Two semi-circular structures, now covered by the city of Toledo, were described by G. K. Gilbert, Vol. I, Geological Survey of Ohio, 1873. Although no mounds or fortifications are known within the limits of our county, the characteristic implements are here found, and we are certain that this interesting type of savage man roamed its forests, drank from its clear springs and navigated its waterways. History opens with tribes of the great

Algonkian nation in possession of this region; the Ottawas, Chippewas and Pottawattomies. The Wyandottes, or Hurons of the French, originally dwelt upon the St. Lawrence and are believed to have their descent from the powerful Iroquois of New York. They were, however, attacked by the latter, driven to Michigan and continually persecuted by them, being at one time almost annihilated.

§ 7. Early settlements.

Col. Francis Navarre is credited with being the first white settler within the present limits of Monroe county. He settled in 1780 near the mouth of the River Raisin, known by the Indians as "Namet Cybi," and in 1785 secured from his "Pouteouatamie" friends a deed to a considerable tract of land, lying south of the river, which land is still largely held by his descendants. In 1784 over one hundred families of Canadian French arrived and founded Frenchtown, upon the north bank of the Raisin, opposite Monroe. The same year other French families settled along the creeks to the north and south.

§ 8. War of 1812.

This part of Michigan was a portion of New France up to the year 1763, when it came into possession of the British and was actually held by them until 1796, although nominally transferred to the United States in 1783, at the clase of the Revolution. By Hull's Treaty of Detroit, in 1807, the Indian titles to lands in the county were extinguished, except nine sections of land upon the Macon reserved for the above four tribes. Encouraged by the British these Indians became unfriendly and during the War of 1812, the eastern part of the county became the scene of bloody hostilities. Marching to the relief of Detroit Gen. Winchester, with 1,000 Kentucky troops, was surprised January 22, 1813, by British and Indian allies and suffered a most crushing defeat; nearly all being killed or captured. The scene of the battle and the terrible massacre, was on the banks of the Raisin, about a mile east of the site of Frenchtown, but as the river was frozen it extended southward as far as the poor soldiers succeeded in eluding their savage pursuers. Gen. Winchester, who was spending the night at the cabin of Col. Francis Navarre, was himself captured and taken to Fort Malden, Canada. "Remember the Maine" is but a paraphrase of the Kentuckians' "Remember the Raisin," used later as a battle cry. In 1818 the bones of the unfortunate troops were collected and buried with honors at Detroit in the Protestant burying ground. In 1849 they were transferred, along with others from the battlefield, to Frankfort, Kentucky. The disgraceful surrender of Detroit in August, 1813, was followed within less than a month by the glorious naval victory of Commodore Perry and the stars and stripes again soon floated over the city. Five times had the flag changed within the half century.

§ 9. Growth of population.

These frontier troubles and the malicious report of the government agents in regard to the soil and climate of this portion of the State had much to do in retarding its development. The entire white population of the territory in 1800 was 551, in 1810 but 4,762, of whom nearly one-third were in Monroe county. During the next ten years it increased to 8,896 only, but jumped to 31,639 from 1820 to 1830. In the decade during which the territory acquired statehood, the growth in population was most surprising, reaching 212,267 in 1840. Owing to its fertility, location and natural resources Monroe county had more than its share in this increase. The following table tells the story of its gradual development:

1810— 1,340 .... 1860—21,593
1820— 1,831 .... 1864—22,221
1830— 3,187 .... 1870—27,475
1837—10,611 .... 1874—30,111
1840— 9,922 .... 1880—33,624
1845—13,861 .... 1884—33,353
1850—14,698 .... 1890—32,337
1854—18,030 .... 1894—33,181

§ 10. Southern boundary.

Before the present boundaries of the county were finally established the question of the line between the State of Ohio and Michigan Territory had first to be settled and this brought on the temporary turmoil, known as the "Toledo War." The celebrated "Ordinance of 1787," by which the Northwest Territory was organized, provided that the boundaries should be altered "so as to form one or two states in that of the said territory which lies north of an east and west line drawn through the southerly bend, or extreme of Lake Michigan." The map which was then regarded as official was the "Mitchell map," published in 1755 before any accurate survey of the lake had been made, and this map represented Lake Michigan as terminating at latitude 42° 20′ N. This line passes through the city of Detroit and if the apparent intention of the framers of the ordinance had been carried out the writing of the geological history of Monroe county would have been done by the Ohio Survey. It was ascertained later that Lake Michigan extended much further south and that this east and west line would somewhere strike the western or southern shore of Lake Erie. The act of the Senate and House of Representatives of 1802, authorizing the State of Ohio to form a constitution and state government, placed the boundary "on the north by an east and west line drawn through the southerly extreme of Lake Michigan, running east, after intersecting the due north line aforesaid, from the mouth of the Great Miami, until it shall intersect Lake Erie, or the territorial line, and thence, with the same, through Lake Erie, to the Pennsylvania line aforesaid." The constitution of Ohio provided, however, that if this line should intersect Lake Erie east of the mouth of the Miami of the Lake (Maumee), then the northern boundary should be a line run direct from the southern extreme of Lake Michigan to the most northerly cape of the Miami (Maumee) Bay. The acceptance of the Ohio constitution, containing this clause, was regarded by the State as authorizing this boundary line, although not so regarded by Congress itself. This line was run in 1817 by surveyor Harris and was known as the "Harris Line." The line claimed by Michigan, namely, that drawn due east from the southerly extreme of Lake Michigan, was known as the "Fulton Line" and between them there was included the strip of land in dispute five miles broad at the west, eight miles broad at Lake Erie and about seventy miles long. Perhaps no serious differences would have occurred between the territory and state if the Erie canal from Cincinnati had not been headed for Toledo, which it would make its northern terminus with all the supposed advantages only on condition that it was a part of Ohio. The attempt to re-mark the Harris Line in 1835 precipitated trouble, the militia from each section being called out and brought almost face to face with one another. Michigan was, however, applying for admission to the union of states and was compelled by Congress to accept as its southern boundary the line claimed by Ohio. This it did most reluctantly and was given as a reward to soothe ruffled feelings, the entire upper peninsula.

C. *Geological Work within the County.*

§ 11. Previous work.

Nothing in the way of systematic geological exploration was attempted in the region covered by this report so long as Michigan remained a territory. Something was known, however, of its natural resources and the pioneers and traders had begun to utilize its economic products. The principal limestone outcrops had been located and rock removed for lime and building purposes. Quarries had been opened in the Raisin bed at Monroe and Dundee, also in the beds of Swan, Stony, Plum and Bay creeks, upon the Macon and at the head of Ottawa lake. In the region of the natural outcrops, particularly upon the "ridge," stone had been superficially quarried. Lime had been burned upon Plum Creek, at Ottawa Lake and at the Macon quarries. The bed of glass sand seven miles northwest of Monroe had been opened and found to produce a good quality of glass. Brick had been burned at Newport, Brest, Dundee and in London township, upon the Saline. The salt springs along the latter stream were known and utilized in an early day by both Indians and settlers.

§ 12. Houghton survey.

Upon the acquisition of statehood Michigan immediately established a "Geological Survey," the act of the Legislature being approved by Gov. Mason, February 23, 1837. Dr. Douglass Houghton was appointed State Geologist, with Bela Hubbard and C. C. Douglass, Assistant Geologists, and S. W. Higgins, topographer and draughtsman. During the summer following a hasty examination was made of the county by Dr. Houghton, having chiefly for its object "the determination of the rock formations, their extent and order of superposition." Under the head of the "Grey Limestone" he speaks of its outcropping edge as extending from the rapids of the Maumee to those of the Raisin, "which may without doubt, be considered identical with the mountain limestone of European geologists."*

The silicious nature of the limestone encountered in ascending the Raisin was noted and from such beds the glass sand layer was stated to have been derived by disintegration. Calcite, as "hog tooth spar" was observed at Monroe; celestite and tremolite (strontianite?) at

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*1838. Report of the S. G. (first annual.) H. D. No. 24, pp. 276-317; separately, No. 14, pp. 1-39; p. 7.

Brest. The deposits of marl and the mineral springs to the south of Monroe were briefly described. Brine was stated as occurring north of a line drawn from Monroe to Granville, Kent county, which line strikes across the county just south of its northwest corner. As an appendix to his first report, Dr. Houghton published a series of suggestions to those residents disposed to assist in the work (In Senate, February 1, 1838), and 115 questions pertaining to the bed rock, soils, water supply, subterranean forests, peat, marl, iron ore, streams, lakes and surface boulders.

The detailed study of Monroe county was assigned to the assistant Bela Hubbard and was reported upon in the Second Annual Report, February 4, 1839.[*]

The general topography of the surface, its springs and streams, the soils, subsoils, and timber were studied and described. The natural and artificial rock exposures were visited and the strata determined to be dipping northwest, or northwest by north, at an angle of about 5°. This dip was afterwards[†] lessened to 15 feet to the mile, but found to vary from 10 to 20 feet.

No attempt was first made at the correlation of these strata with one another, or with those of other regions. Beds of peat and marl were located and their use in the amelioration of the natural soils repeatedly emphasized in the reports. The "Lake ridge," which cuts across the northwestern corner of the county, extending for many miles in either direction, was correctly interpreted as marking the former extension of the lakes. The abrupt change which here occurs in the topography, as well as in the character of the soil and the timber was noted and clearly understood. The surface boulders were termed "erratics" and were recognized as having been transported by some imperfectly understood agency from the north. The surface scratches upon the limerock at Brest and Point aux Peaux were measured and found to be N. 50° E., N. 60° E., N. 65° W. They were ascribed to the "attrition of hard bodies moving in a strong current," (p. 113). In the same report (Second, p. 65), Higgins announces the completion of his topographic map of the county, but if it was ever published all trace of it seems to have been lost. It was very probably similar to his map of Wayne county which appeared the next year in the Third Annual Report.[‡]

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[*] Second annual report of the State Geologist. H. D. No. 23, pp. 380-507; S. D. No. 12, pp. 264-391.

[†] Fourth Annual Report, p. 135; H. S. and J. D. No. 11, pp. 472-607, separately H. D. No. 27, pp. 1-184; p. 135.

[‡] Annual report of the State Geologist (third, map of Wayne county): H. D. No. 27, Vol. II, pp. 206-293; S. D. No. 7, Vol. II, pp. 66-153, separately No. 8, pp. 1-120.

A still more detailed study of the geological features of the county was made by Hubbard and further reported upon in the Third Report, above referred to. The limestone was stated to occupy a horizon higher geologically than the blue limestones and shales of Cincinnati (Hudson River Group), but to be below the "black strata" (St. Clair shale), and without doubt is equivalent in position to the "Cliff limestone," of Indiana (p. 83). Three belts of rock, with quarries and outcrops, were recognized as crossing the county in a northeast and southwest direction. The most easterly, and consequently the oldest, is described as a compact limerock, light gray to blue in color, sometimes veined, sometimes oölitic, and carrying distinctive fossils. The most westerly range, highest both topographically and geologically, is somewhat sparry, geodiferous and bituminous, carrying some fossils of a different species from the former. The middle range consists of highly silicious rock, passing into pure sandstone. The individual grains of the glass sand he recognized as consisting largely of perfect quartz crystals. The term "diluvium," or "diluvion" was applied to what is now known as the "drift," made up of "detritus of the upper portion of our coal series, which has been broken up and washed away, and in part of sands and fragments of the primary rocks, transported from a more northerly region." (p. 83). The following, quoted from page 89 of this report, is of interest since it furnishes a clear, concise statement of the views held sixty years ago, and not yet entirely discarded, concerning the origin of this "diluvium."

> "It has been already remarked that in general all the rocks are covered with a mantle of clays, fine detritus of the lime and sand rocks, or loose water-worn fragments of still older rocks, swept from the north by the currents of a universal ocean and deposited during the general subsidence. Some evidences of the direction of these currents were noticed in my report of last year. Among these are the diluvial furrows and scratches on the surface of the limerock, the appearance and direction of which correspond with observations made in some of the more eastern states."

Allusion is made in the next report (Fourth p. 116), to Lyell's iceberg theory, as though the above explanation was not entirely satisfactory. In discussing the origin of the erratics he remarks that they came from the north "Whatever may have been the causes which swept these materials over the face of the rocks, whether oceanic currents or bodies of *floating ice*."

Owing to the inaccessibility of the reports of this first geological survey Hubbard is not generally credited with the work which he did in the way of deciphering, at this early day, the history of our great lakes. Mention will be made of this again in connection with the glacial history of the county. The deposits from the ancient bodies of water he termed "alluvions" to distinguish them from the "diluvion" described above, and "ancient alluvions" to distinguish them from the "recent alluvions," now forming, or having been very recently formed, as marl, peat and bog ore. The "Tertiary clays" (till) were regarded as present in Monroe and Wayne counties, as well as over two-thirds of the lower peninsula. In the Fourth Report (p. 109) Douglass identifies certain limestones in the northern part of the peninsula as Corniferous, and correlates them provisionally with those of Monguagon (Trenton) and hence also with those on the Macon. The geological formations identified and differentiated by this survey, so far as Monroe county is concerned, are shown below.

6. Recent Alluvions.
5. Ancient Alluvions.
4. Diluviums, or Erratic block group.
3. Tertiary clays.
2. Black aluminous slate.
1. Limerocks of Lake Erie.
    c. Corniferous.
    b. Silicious limestones, passing into sand.
    a. Compact gray or blue limestone.

§ 13. Winchell Survey.

With the accidental drowning of Dr. Houghton in Lake Superior, October 13, 1845, further geological work ceased in this region and was not resumed again until the Second Geological Survey was organized by Dr. Alexander Winchell in 1859. In the meantime new outcrops had been discovered, new quarries had been opened and old ones deepened. Many wells had penetrated to the rocks, giving information in regard to the surface deposits and in regard to the rocks themselves. Much geological and palæontological work had been done in New York, and Canada, calculated to throw light upon Michigan geology. Dr. Winchell began his field work in May, 1859, with a re-examination of Monroe county, assisted by two of his students, Messrs. A. D. White and Lewis Spalding. Owing to the large amount of territory to be covered, only a short time could be devoted to this region. The First Biennial Report, published in 1861, contained the results of this field work* (pp. 58-68). The light colored, argillaceous limestones of the Davis quarry, west of Ida, were identified as those of the Onondaga Salt Group, on account of the gypsum present. The same beds were believed to appear at Ottawa Lake and to be struck in the deeper portions of the Plum Creek quarries, and the suggestion is made that gypsum be sought for at these localities, as well as in the gorges of Otter Creek. The thickness of the Onondaga in Monroe county is given as 24 feet; the first 10 feet of which is a chocolate colored limestone, the remainder fine ash colored, argillaceous limestones, with acicular crystals (p. 140). The Upper Helderberg is given a thickness of 60 feet in the county, and was made to include the brecciated dolomites of Stony Point and Point aux Peaux, the two beds of oölite, the Sylvania sandstone and the purer limestones on the Macon.

The work of the survey was interrupted by the War of the Rebellion and not resumed again until 1869, with Dr. Winchell again State Geologist for two years. Materials for a valuable volume were prepared but were never published in the manner intended. Some of it, however, appeared in Walling's Atlas of Michigan and was subsequently put out (1873), as a small volume bearing the title "Michigan." The occurrence of the Lower Helderberg (Waterlime) had been announced in 1870. This formation was recognized in the quarries in the eastern part of the county and considered to attain a thickness of 60 feet. The geological map which accompanies the volume gives a narrow strip of Lower Helderberg, three to four miles wide, following the shore of Lake Erie, with a broad belt of Corniferous to the west and embracing nearly the entire county. Small islands of Salina, with marginal strips of Lower Helderberg, are represented at Ida and Ottawa Lake, and apparently also at Monroe and Brest. The Little Traverse appears as a narrow belt, with the general strike and position which the Corniferous ("Dundee") is now known to possess, while the Huron shale covers the remaining northwest corner of the county. This corner is just grazed by the Marshall sandstone. The formations which overlie the Lower Helderberg are thus seen to be displaced to the east. The following "generalized section" was intended to include all the Monroe county beds, excepting the Little Traverse and Huron, which are not here known in outcrop.

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*1861. First biennial report of the progress of the G. S. of M. Embracing observations on the Geology, Zoology and Botany of the Lower Peninsula. Made to the Governor Dec. 31, 1860.

IV. Brown bituminous limestones, seen in most of the quarries of Monroe county; also in Presque Isle and Emmet counties, 75 feet.

III. Arenaceous limestone, sometimes resolving itself into beds of friable sandstone and incoherent sand. Monroe county; also Crawford's quarry, 4 feet.

II. Oölitic limestone, as in Bedford and Raisinville, Monroe county, 25 feet.

I. Brecciated limestone, sometimes concretionary, 50 feet.

§ 14. Rominger survey.

Dr. Carl Rominger began his examination of the rocks of our southern peninsula in 1873, making a detailed, careful study of all the beds and their fossil contents. The results of his three years' personal work are recorded in Vol. III, Geological Survey of Michigan, 1876. That portion of the report which deals with the rocks of Monroe, and the adjacent portions of Wayne county is recorded on pages 25 to 37. The limestones of this region he described under the single heading "Helderberg group," but recognizes an upper and lower division, equivalent to the Upper and Lower Helderberg respectively. The lithological characters of the beds are accurately noted and simple analyses given of the more important, some of which will be incorporated into this report. The Sylvania sandstone he gives a thickness of but 8 to 10 feet and, following the earlier reports of the Ohio Survey, regards it as probably the equivalent of the Oriskany sandstone, of New York (p. 29). The oölite of Plum Creek and Little Lake he regards as the geological equivalent of the sandstone (p. 28), being misled by the beds of mottled dolomite which underlie each, but which are actually many feet apart. A still more serious error was made in bringing the base of the Upper Helderberg down to the top of the Sylvania sandstone, based upon the lower percentage of magnesia in these beds. The quarries of Ottawa Lake, Little Sink, Lulu, Ida, Raisinville, Woolmith and Flat Rock are all in beds above the Sylvania and still contain practically enough magnesia for normal dolomite. Both lithologically and palæontologically these beds immediately above the Sylvania must be connected with those beneath.*

Dr. Rominger does not admit the occurrence of the Hamilton

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*See Geological Survey Ohio, Vol. VII, p. 17.

(Traverse) in this portion of the State (p. 38), believing that from the thickness of 500 feet near Alpena, it thins out completely before reaching the southern boundary. Reasons will be given later for thinking that the Traverse is well represented beneath its heavy mantle of drift in the northwest corner of the county. Upon the geological map that accompanies Vol. III the structure of Monroe county is much simplified by uniting the Upper and Lower Helderberg into one division, not representing the Sylvania and imposing the St. Clair shale directly upon the Upper Helderberg.

§ 15. Work of present survey.

While searching for natural gas in the early fall of 1887 at the plant of the Eureka Iron and Steel Works, in Wyandotte, the drill from 730 to 1,235 feet passed through a series of layers of pure rock salt. The newspaper announcements of this incidental discovery caught the eye of interested parties in the East and experts were soon upon the ground. The remarkably pure beds of limestone, two miles distant, combined with unusual shipping facilities, made the region almost an ideal one for the manufacture of soda ash and caustic soda. Establishment after establishment has sprung up along the Detroit River, representing millions of outside capital and employing an army of workmen. Other extensive plants are seeking locations and are inquiring for high grade limestone. The rapid development of the Portland cement and beet sugar industries in our State has greatly increased the demand for natural products.

The records of the Wyandotte well above mentioned and of a well at Monroe down into the Trenton which were collected during the administrations of State Geologists C. E. Wright and M. E. Wadsworth were printed in Part II. of Vol. V of the State Reports. There is also a geological map of the lower peninsula in this volume, which shows the course of the Sylvania sandstone, and the terms applied to the various members of the rock series which we use. During this time the records of the Dundee and other wells were acquired by the State Survey, and by the spring of 1896 it was decided to arrange for a thorough survey of this most promising corner of the State and to render available at once, by means of a bulletin, what could be learned of its resources. The work was begun under Dr. Lucius L. Hubbard and after his resignation, continued and completed under the present organization. July and August, 1896, and August, 1897, were devoted to the field work by the writer, assisted the first season by Mr. W. D. Cramer and later by Messrs. R. R. Putnam and De Forest Ross. For purposes of comparison, a careful study was first made of the extensive Sibley quarry, north of Trenton, and of the smaller quarries and outcrops about the Detroit River. Within the county every known natural and artificial exposure of the rocks was visited, the strata studied, samples and fossils collected and each quarry platted. From convenient centers, a study was made of the soils and their distribution and much detailed information gathered in regard to the depth and character of the rocks, the nature of the drift deposits, water supply, timber and crops, indications of oil, gas, etc. From Ottawa Lake a side excursion was made into Ohio to examine the exposures of the Sylvania sandstone and adjacent strata. The delay in the publication of the bulletin necessitated a final general survey of the county, in order to bring the information to date and nearly two weeks in September, 1899, were devoted to this purpose. The Raisin was found to be exceptionally low and a favorable opportunity was afforded for studying the strata over which it flows. As to the results secured and conclusions reached the body of the report must be allowed to speak.

§ 16. Acknowledgments.

It is a pleasure to acknowledge here the uniformly courteous treatment received from the farming population of the county. Much of this report has been rendered possible only through information received from them. Only in a few cases, where they feared that they were being victimized by some new scheme, was information withheld or grudgingly given. It is hoped by getting the benefit of generalizations, based on their combined knowledge, that they may be, in part, at least, repaid. The numerous well drillers, with but a single exception, have given their valuable information, the result of years of labor and the expenditure of much money, freely and gladly. Especial acknowledgment is due Mr. John Strong, of South Rockwood, and his driller Mr. H. S. Dalton, for information and series of samples of the Newport well. To Church & Co., through their courteous manager Mr. K. J. Sundstrom, the survey is very especially indebted for maps, charts, negatives, analyses, and valuable information pertaining to the region, with every facility for the study of their extensive Sibley quarry. The same generous treatment was accorded by Mr. G. F. Smith, at the time president of the Michigan Stone & Supply Co., and by the officers of the Monroe Stone Co. We are indebted for our topographic base very largely to the county atlas published by Geo. A. Ogle and Co., of Chicago in 1896. Finally, to Mr. Ezra Lockwood and family, of Summerfield township, grateful acknowledgment is made for generous hospitality, conveyances and valuable information, the result of many years' intelligent observation and experimentation in the prairie region.

CHAPTER II.

DEVONIAN AND QUATERNARY FORMATIONS.

A. Quaternary Deposits.

§ 1. Thickness.

Except over areas covering but a few square yards, the rock beds of the county are concealed by a mantle of more or less unconsolidated material, varying in thickness from a few inches to about 150 feet. The average depth would probably be from 40 to 50 feet, although there are many square miles within which the depth to the rock is less than 25 feet. The deepest beds of this covering are found in the northwestern corner of the county, where just southwest of Milan, they reach a thickness of 150 feet. In the southeastern part of Erie township a thickness of 80 to 90 feet is attained. Extending in a northeast and southwest direction there are three belts along which this superficial covering is very much less, in some instances being practically absent and thus exposing the bed-rock. The most easterly belt of the three begins in the southern part of Whiteford township, extends northeastward across Bedford, northwestern Erie, the western part of La Salle, through the city of Monroe to Brest and into the eastern part of Berlin township. Throughout this entire extent the deposit rarely exceeds ten feet in thickness and is on an average much less, hence it is accompanied by numerous quarries and natural rock exposures. The middle belt is approximately parallel to the eastern just located and extends from Ottawa Lake sink, through the northeastern corner of Whiteford, across Ida, western Raisinville into the southern part of Exeter township, beyond which the deposit increases to 30 to 40 feet. Upon the map (Plate XV), there is shown by means of the contour lines, the depth of the rock from the general surface of the land. These contours thus show, also, the thickness of these deposits referred to. Just where the sand accumulations of the Forest Beach are added to those of the clay, an apparent deepening of the rock occurs as shown by the contours on either side of Lambertville and in Sections 19, 20 and 21, of Ida township. The third belt is less well defined, shorter and more interrupted, the thinner portions of the drift being located at Petersburg, Dundee and on the Macon, where it is but two feet thick.

§ 2. General nature.

The great bulk of the deposit above referred to constitutes the so called "drift," an accumulation for which the great continental ice sheet, to be later described, was responsible. This consists, in the main, of a great mass of stiff, blue clay, entirely without stratification and carrying varying proportions of sand, pebbles and boulders. This is technically known as "till." When thoroughly compacted and filled with stones it is popularly called "hard-pan," in which form it greatly retards the operations of ditching and well digging. Upon exposure to the atmosphere, as at the surface or by means of a natural or artificial excavation, the color changes from blue to yellow or a rusty brown, owing to the oxidation of the iron. The alteration in color may extend but a few inches, or it may reach to a depth of fourteen feet or more, as about Dundee. The change in color marks the lower limit of percolating surface water, which depends upon the structure of the bed itself. Embedded in the clay there are frequently encountered lenticular masses of "quick sand," more or less stratified and of varying thickness and extent. Less frequently beds of gravel, from fine to coarse, are encountered, but are probably not continuous under any considerable area. Some of the deposits reported as "gravel" by farmers and drillers are beds of sand simply, or till rather more heavily charged with pebbles than is usual. This is probably true of the beds of "cobble stones" reported as occurring at a depth of 25 feet in Sec. 20 (S. W. ¼, S. W. ¼) of Ash. At the bottom of wells in Sections 4 and 6, and in Sec. 20, at a depth of 30 feet, Milan township, a bed of gravel is reported. In Section 9, still nearer the surface, a three foot bed is said to occur, overlain by 13 feet of clay and underlain by hardpan. Southward in Dundee township, Section 8 (T. 6 S., R. 6 E.), gravel was encountered at 28 feet, and in Section 26 was found overlying the rock. Eastward in London township, Sec. 20, a fifty foot well stopped in gravel. In Summerfield township similar reports of gravel strata were obtained from both farmers and drillers. It overlies the rock in Sec. 4, with a heavy bed of blue clay above, but is struck in Sec. 7 at a depth of 14 to 16 feet and furnishes water at the place of T. M. Taft. In the same section (N. W. ¼, S. W. ¼), at John Long's place, coarse gravel was reached at a depth of 53 feet, overlain by a three foot bed of "putty clay." The gravel was penetrated three feet and the well abandoned because the hole could not be kept clean. In Sec. 27 there is on an average 1½ feet of a sandy loam, one to six inches of blue clay and beneath a stratum of rounded pebbles varying from the size of a pea to that of the fist. The layer is four to six inches in thickness, but may be represented by a few stones simply. Beneath this is a heavy deposit of yellow, followed by blue, clay and hard pan. In Bedford township, Sec. 4 (N. E. ¼, N. W. ¼), a 3 to 4 foot bed of gravel is stated to overlie the rock, which is struck at 26 feet. With the exception of the last record all the reputed layers of gravel occur within the limits of Summerfield, Dundee, Milan and London townships. Some of them may be merely inclined gravel filled fissures or cracks.

§ 3. Boulders.

Scattered rather sparingly over the clay areas of the county are rounded masses of crystalline rocks, such as are known in place—nearest in Canadian regions to the northeast. In the western and northwestern portions of the county they repose directly upon the surface, but eastward are more and more embedded in the soil and frequently struck only with the plow. They consist in the main of gneisses, schists, diorite and diabase, and, occasionally, limestone, sandstone, and conglomerate. A well known type of the latter is represented by a boulder 6x3x2½ feet lying along the roadside at the S. W. ¼, N. W. ¼, Sec. 3 Milan. It contains rounded pebbles of brown and bright red jasper, very characteristic and readily recognized. The parent bed is in western Ontario, north of Lake Huron, and its fragments are found in Ohio, Indiana, Illinois, Wisconsin and even so far south as Kentucky and west as Iowa. In size these boulders vary from cobble stones, and less, up to masses weighing many tons. One of the largest in the county, and probably the largest in this section of the state, lies about one and one-half miles east of the village of Ida, upon the farm of Christopher Knapp, claim 521. It is an enormous mass of hornblendic gneiss, contorted, of a light gray color, having a length of 20 feet, maximum breadth of 15 to 16 feet and standing four feet above ground (See Fig. 1). Presumably there

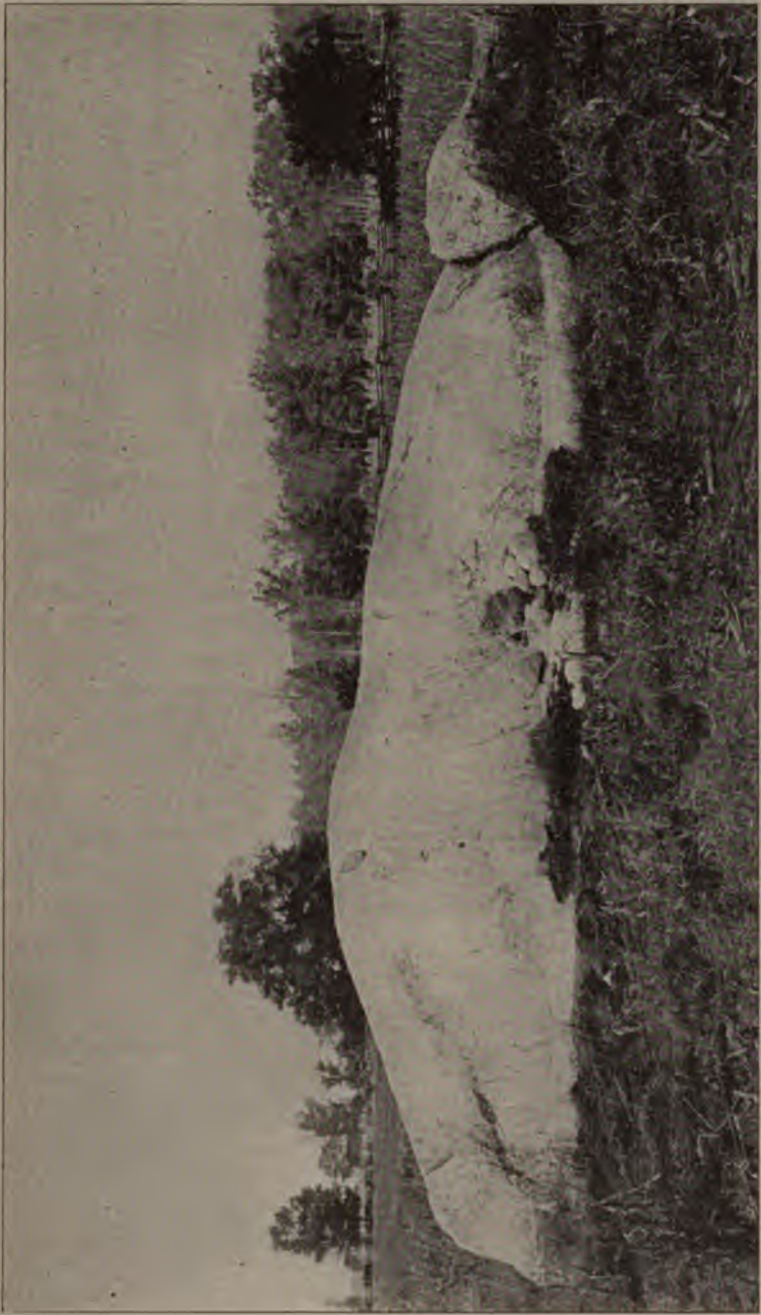

Fig. 1. Mammoth boulder transported by the great ice sheet and dropped east of the site of Ida. Four feet above ground; twenty feet long.

is as much or more below the surface as there is above, and it can scarcely weigh less than two hundred tons. A large fragment of what appears to be identically the same rock lies upon the S. E. ¼ of Sec. 27, Whiteford township, farm of F. B. Doty. The boulder is 6x10x3½ feet and there is said to be as much rock beneath the surface as in sight. Smaller fragments of the same rock are seen farther south.

A mass of limestone, large enough to be mistaken for an outcrop, lies in the western part of Frenchtown township, upon the property of Alexander Stewart (claim 21, N. River Raisin). It formerly projected above ground but building stone has been removed from it and there is now an opening into it 10 by 18 feet, containing three to four feet of water. It is of a light gray color, has a strong bituminous odor, is rich in corals and brachiopods and effervesces vigorously in dilute acid. It lies directly over a bed of sandy dolomite, very different in its nature from this material. Mr. Frank G. Strong, of Monroe, at one time did some boring about the mass and informs me that upon one side only was rock struck with the auger. It seems very probable that we have here an unusually large mass of Corniferous limestone, which was pushed, or carried, beneath the ice sheet from a point a few miles to the northeast and finally left embedded in the clay. In 1865 Winchell described numerous masses of exactly this nature, occurring in the northern part of Lenawee and Hillsdale counties, the southern and eastern portions of Jackson and southern and western Washtenaw.* These masses were occasionally so large that they were mistaken for outcrops, lime-kilns were erected and lime burned until the supply of stone was exhausted. From an examination of their fossil contents Winchell identified them as Corniferous and concluded that their state of preservation was such that they could not have been transported from the outcrops of this formation known to occur about Mackinac. All the masses of this nature then known lay to the north of the Corniferous outcrop in southern Michigan and northern Ohio and Indiana. The conclusion was reached that they had been frozen into the shore ice of a lake or sea, detached and floated northward, where they were gently dropped upon the melting of the ice floe. The evidence of a northward transportation of drift was further strengthened by the finding of delicate Hamilton and Marshall fossils as much as thirty miles north of the southern outcrops of these beds. In the case of the Stewart boulder described, we have an apparently identical mass of limestone lying to the south of the outcrop supposed to have furnished the others. The position of the Corniferous, Hamilton and Marshall beds in eastern Michigan and western Ontario is such that a movement of the ice sheet S. 60° W. would account for the location of the most northern masses described as occurring in this portion of the state, with a maximum journey less than one-half that required to bring them from the northern outcrops. At Stony Point Winchell found glacial striations bearing S. 60° W. This same set occurs at Point aux Peaux, and strikes S. 65° W. at Brest, according to the earlier observations of Hubbard. The glacial striæ, however, found at Trenton and several localities in Monroe county show conclusively that the ice sheet itself actually moved northwestward upon the northern side of the Erie lobe (Chapter VI, § 7), so that the journey made by the rock masses may have been a still shorter one. Much more extensive masses of the same character occur in northern Illinois near Freeport and were described in 1897 by Hershey in a paper upon "The Eskers of the Kansan Epoch."[*] These are referred to later by Leverett in his recent monograph on the Illinois Glacial Lobe under the heading "Transported rock ledges."[†] Some of these masses have not been so gently handled and consist in part of angular fragments of the limestone. Two of the largest taken together are stated to cover 100 acres and to attain a maximum thickness of 40 feet. According to Hershey they were pushed along in front of the ice and were never overridden by it.

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*Some Indications of a Northward Transportation of Drift Materials in the Lower Peninsula of Michigan. Am. Jour. of Sci., Second Series, Vol. XL, pp. 331 to 338.

Only in Berlin and eastern Frenchtown is there any bunching of this surface material sufficient to suggest a morainic deposit. From Stony Point northward the boulders are more abundant, especially upon the "ridge," where the covering of clay is light. In several places the ground is greatly encumbered with cobble-stones, especially upon claims 528, 529, 530 and 531 (N. Stony Creek). In Berlin township, S. W. ¼, Sec. 33, the same cobbles occur in great abundance. It will be shown in another connection that these deposits mark the southern prolongation of a well defined, water-laid moraine, extending from the Huron River northward past Trenton, towards Detroit. (Chapter VI, § 8.)

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[*] American Geologist. Vol. XIX, pp. 197-209, 237-253.

[†] The Illinois Glacial Lobe. Monograph XXXVIII, U. S. Geol. Surv., 1899, pp. 82-84.

§ 4. Post-glacial deposits.

Under the head of Quaternary belong not only the drift deposits described but others of an entirely different nature and history, which will be only briefly referred to here. Spread over nearly the entire till area of the county, is a layer of dark clay loam; very thin or absent in the western part, but increasing in thickness toward the east and southeast. Its absence over certain areas may be due to erosive agencies. It is quite free from pebbles, shows no distinct stratification, owes its dark color to organic matter and is, agriculturally, of very great importance to the county. No sharp line of demarcation exists between this superficial deposit and the underlying till, one seeming to grade into the other.

Passing northward from Sylvania, Ohio, to Oakville is a broad, irregular belt of surface sand, varying in breadth from two to eight miles. In many places the sand has been heaped up by wind action into mounds and ridges, the latter of which sometimes squirm across several adjoining sections. Near Temperance there branches off from this main belt a secondary one, extending northeastward to Carleton and beyond (See map, Plate VII). This is narrower and much more irregular, but otherwise similar. Transverse belts of similar sand almost completely connect these two belts in Raisinville and Exeter townships. From Milan village there extends southwestward across the township, through Dundee to the northwestern corner of Summerfield, a fairly continuous, but narrow strip of yellow sand, with occasional pebbly patches upon either side.

In addition to the clay and sand deposits of such wide extent, there are others, of a more local nature, to which attention may here be called. Along the rivers and smaller streams terraces of silt have been formed, of considerable breadth and thickness and consisting of clay, sand and organic matter. The surfaces of these terraces constitute the flood plains, in general, and receive slight additions with each inundation. Locally, where there have been lakes and marshes, or where these still exist, beds of marl, peat and bog-ore are found, or are now in process of formation. About some of the extensive springs, the waters of which are highly charged with lime carbonate, deposits of calcareous matter over leaves, twigs and moss, result in the formation of a "tufa."

B. Devonian Formations.—St. Clair (Genesee) Shales.

§ 5. General arrangement of Devonian formations.

If all the deposits which have just been described were removed and a general view could be had of the so called "bed rock," it would appear, approximately, as is shown upon the map (Plate I). This constitutes what is called a geological map, in which the belts of color represent certain groups of strata, which have a common structure, composition and history. Being formed within the limits of the same geological period certain distinctive names are assigned to these groups, or to their subdivisions. In Monroe County these strata all have a general northwesterly "dip," with their outcropping edges extending ("striking"), in a northeast and southwest direction. Obviously the strata which were latest formed are in the northwestern corner of the county and the next oldest, in succession, would be encountered as one passed southeastward, across the line of strike. This order of position will determine the order of description of the rock formations.

§ 6. Name.

The youngest member of this Monroe County series is the group of "St. Clair shales,"[*] so named from their occurrence along St. Clair River. They constitute the lower portion of Winchell's "Huron Group," described in his report of 1861 (pp. 71-80). In the early Ohio reports the beds are referred to as the "Huron shale," "Black shale," "Black slate," and "Shale stratum." Newberry in his report of 1873[†] describes two beds of shale, the Erie and Cleveland, which immediately overlie the Huron. These three were united by Orton into a single stratum which he termed the "Ohio Shale."[‡] An upper and a lower division were recognized, for the latter of which he retained the name Huron shale, and it is this which forms the northwestern corner of Monroe County (See Map I). It is probably nearly equivalent to the Genesee shale of the New York series.

§ 7. General data.

Only about seven sections of the northwestern corner of Milan township are underlain by these shales, the main portion of the stratum lying in Lenawee and Washtenaw counties, and dipping at a low angle to the northwest. They are covered by 100 to 150 feet of drift and so are struck only in the relatively deep wells of this region. The actual elevation of the base of the stratum is about 560 feet above tide at Milan (18 feet below the level of Lake Erie), while the elevation rises to 610 feet where it leaves the county. The highest elevation noted is in the extreme northwestern corner of Section 6, where it is about 625 feet above tide. Winchell gives an outcrop of shale of his Huron group as occurring near Adrian, Lenawee County.* If such an outcrop occurs the shales cannot be the St. Clair since these were struck in the well of the Adrian Gas Company at a depth of 524 feet from the surface. Good exposures, however, are found northward about the shores of Lake Huron and along some of the small ravines leading back from the lake.

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[*] Geol. Sur. of Mich., Vol. V, 1895, pt. II, p. 21.
[†] Geol. Sur. of Ohio, Vol. I, pp. 152-167, 189-191.
[‡] Geol. Sur. of Ohio, Vol. VII, 1893, pp. 21-26.

§ 8. Thickness.

In the Adrian well above referred to, the shales regarded by Lane as the St. Clair show a thickness of 221 feet.† At Ann Arbor in the court-yard well, they appear to have a thickness of 275 feet, according to the same authority.‡ In Ohio these shales show a development of about 300 feet and in western Ontario at Corunna, Lambton county, 213 feet. At Sarnia, according to Brumell, they are reduced to 80 feet. The base of the bed at Ann Arbor has an elevation of 134 feet above tide; at Milan 560 feet, giving a drop in the fourteen miles, in this direction, of 426 feet, or about 30.5 feet to the mile.

§ 9. Lithological character.

Where well exposed, as upon Sulphur Island, Thunder Bay, these shales are seen to be black, very fissile, hard, crisp and sharp; approaching slate, when unweathered. They possess a certain amount of elasticity, and snap and crackle under the feet, as one walks along the beach. They are finely laminated and very evenly bedded. When exposed to the weather they assume a gray, or rusty brown color, from the oxidation of the contained iron. Efflorescences of sulphates of iron, or alumina, form over the surface where it is somewhat protected from the rain. The color becomes darker towards the bottom of the series, due to the greater amount of carbonaceous matter derived from vegetation. Such shales have an oily appearance and a strong bituminous odor. Beach fires on Sulphur Island are said to have burned as long as 16 months, although, ordinarily, the shales are incapable of sustaining combustion. The spontaneous distilla-

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*First Biennial Report, 1861, p. 76.
†Geol. Sur. of Mich. Vol. V, Part II. Plate 1.
‡Page 47.

tion of this organic matter has yielded large quantities of petroleum and natural gas, products almost always associated with the stratum, in New York, Ohio, Ontario and Michigan. Crystals of pyrite and nodules of marcasite are of common occurrence in the shales. The latter is especially subject to chemical decomposition, forming compounds of iron and sulphur, which stain the shale and impregnate the percolating water. Spherical to ellipsoidal concretions, varying in size from an inch to six feet in diameter, are found embedded in the mass of shale. These consist according to Rominger, of lime carbonate 89%, magnesium carbonate 2%, with 7.5% of insoluble, bituminous and silicious residue. Crystals of calcite and siderite, sometimes with fragments of organic remains, are found toward the center of each concretion. The shales themselves have yielded but few fossils, either in Michigan or Ohio, and those found are mostly of plants. Rominger reports subordinate seams of lime rock showing "cone-in-cone" structure.

A recent number of the Journal of Geology* contains figures and descriptions of the concretions by Reginald A. Daly. The composition is shown to be approximately the same as that given by Rominger. This author calls attention to the deformation of the shale on all sides of the concretion and concludes that they were formed in place within the shale, that they antedate the period of joint development and final consolidation of the shale, and that the deformation resulted from the energy of the process of crystallization, due to a change in volume when the original bicarbonate of calcium was converted into the monocarbonate.

§ 10. Geological position.

Reposing as these lower beds do upon layers of undoubted Hamilton, and with the characteristics above presented, it is exceedingly probable that they are to be correlated with the Genesee shale of central New York. The description of lithological characters would apply as well to the shales about Canandaigua Lake as to those of Thunder Bay. That they cannot be regarded as Marcellus, as has been maintained by some, is proven by their position above the Hamilton beds. As yet, however, the lower portion of the St. Clair has furnished no fossils with which to strengthen this lithological evidence of equivalency with the Genesee. For the last forty years the views of those who have worked in this lake region are not in reality widely divergent. In his report of 1861 (p. 79) Winchell, relying upon the evidence of Billings and Hall says: "In this state of the case we shall be constrained for the present to regard the Huron Group of Michigan, extending from the conglomerate above the gritstones of Huron county, to the top of the argillaceous limestones of Partridge Point, as probably representing the rocks of the Portage Group of New York." In a paper read before the Geological Society of America, in December, 1893, Brumell, of the Canadian Geological Survey, still refers this shale series to the Portage, but in his table includes the Chemung.* According to the later publications of the Ohio Geological Survey, Newberry did not sharply separate his Huron shale, from his Erie and Cleveland above it and in 1873† he reports the occurrence of diagnostic Portage fossils in the Huron, or lowest member of our St. Clair shale. In his chart of geological time, however, he drops the Huron shale to the level of the Genesee. In the Erie he found positive palæontological proof of its equivalency with the Chemung (p. 164). Three years later Rominger referred the entire series to the Genesee.‡ In a little table of the divisions of the Devonian system published in 1886 (Geological Studies, p. 389), Winchell makes the Erie shale of Ohio the equivalent of the Portage and Chemung. The Huron shale he correlates with the Genesee and all together comprise his Huron group. This view harmonizes the apparently discordant views of the various workers and was accepted by Orton. In his report of 1893 he says,§

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*February—March, Vol. VIII, No. 2, pp. 135-150. "The Calcareous Concretions of Kettle Point, Lambton County, Ontario."

"The Ohio shale, as Newberry first proved, is certainly the equivalent in the general scale of the Genesee slate, the Portage group and the Chemung group, the last named being itself a formation of great thickness and extent in New York and Pennsylvania. In other words the shales of our column fill the entire interval between the Hamilton proper and the Catskill group and in the judgment of some geologists a wider interval than that named above."

In a paper upon the Devonian system in Canada, published in October, 1888, W[illegible] [illegible] of the black shale [illegible] New York [illegible] Huron.* [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

§ 11. Lithological history.

The materials of which these shales are composed were accumulated in the off-shore region of the ocean, or some great inland sea. The fineness of the particles indicates that this region was somewhat remote from the land, yet near enough to receive from it, through the agency of waves and currents, the materials resulting from the erosive agencies continually at work. Deposits of such thickness could probably only have been formed over a slowly subsiding sea bottom. Conditions were not favorable for the ordinary forms of marine animals, such as the corals, mollusca, echinoderms and crustacea, and hence the beds are relatively free from the lime carbonate which these forms secrete from the water. The presence of so much bituminous matter indicates that marine vegetation, of a certain type, was very abundant. This bituminous constitutent of the shale is due very largely to the presence of enormous numbers of minute disc-like bodies, with thick carbonaceous walls. These were discovered by Dawson in the shales of Kettle Point, Lake Huron and described by him in 1871, under the name *Sporangites Huronensis.** According to Orton, however, they had been seen previously by B. W. Thomas in the water and clays of Lake Michigan. They are about .01 of an inch in diameter and under the microscope show a papillose exterior, with an attachment scar on one side and a more or less elongated gaping slit upon the other. Remains of *Calamites* and *Lepidodendron* were found in association and Dawson regarded them as spore-cases of the latter tree. Without having seen this article by Dawson, in 1882, Orton described these bodies in the above mentioned journal,† as spore-cases, containing both macrospores and miscrospores. In August, 1883, Dawson read a paper before the American Association for the Advancement of Science, entitled "On Rhizocarps in the Palæozoic Period."‡ From material furnished by Derby from Brazil two new species were described, *S. Braziliensis* and *S. bilobatus.* The spore-cases showed the macrospores in position, so much resembling those of the floating fern of the European rivers, *Salvinia natans*, that the generic name *Protosalvinia* was suggested. His former *Sporangites Huronensis* he considered as the macrospores of related plants, but with their envelopes lost. A similar interpretation is put upon the forms by Clarke who found them abundant in the Marcellus shale of Ontario county, New York. They are associated with immense numbers of minute sub-spherical bodies, regarded as the microspores.[*] These later discoveries are in entire harmony with the view early advanced by Newberry in his Ohio report for 1873, page 156. He there calls attention to the difficulty in conceiving of such widespread shallow water conditions, capable of furnishing the necessary shore vegetation, with the evidence of the proximity of the shore so completely wanting. He referred the bituminous matter to former floating plants and imagined the entire area of the black shales to have been one great "Sargasso sea." Fragments of rushes and trees were occasionally drifted seaward by the same current which distributed the sediments themselves. About such fragments, or the bones and teeth of the terrible fish which inhabited these waters, concretions formed, while the mud was still soft. Later great beds of sediment were superposed, the weight of which compressed the soft material to probably but one-half its original volume, forced out the excess of water and produced the crisp, fissile shale.[†] The pyrite and marcasite were formed wherever soluble sulphates came in contact with putrefying organic matter and oxide of iron, as shown by Bischof many years ago and later by Forchhammer. The sulphates may be derived from the organic matter itself or be in solution in the sea-water in which it is immersed. When sea weeds and iron oxide are in contact double decomposition ensues and the above sulphides of iron result. Forchhammer mentions a beautiful illustration of this action on the western shore of the island of Bornholm where *Fucus vesiculosus* is very abundant, and all the pebbles on the bottom are coated with a yellow coating of pyrite. Upon exposure, however, it is converted into a sulphate of iron. The author concludes with the following clear statement, "Thus it follows, that wherever putrifying sea-weeds come in contact with ferruginous clay, iron pyrites must be formed, which penetrates the clay, and on weathering first forms sulphate of iron, and if no lime be present, will ultimately, by a new decomposition, change into sulphate of alumina."[‡]

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*American Journal of Science, 3d Series, Vol. I, pp. 256-263.

†A Source of the bituminous matter in the Devonian and Sub-Carboniferous Black Shales of Ohio, Am. J. S., 3d Series, Vol. XXIV, pp. 171-174.

‡ Proceedings, 1883, pp. 260-264.

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[*] On Devonian Spores. American Journal of Science, 3d Series, Vol. XXIX, 1885, pp. 284-289.

[†] It should be said, however, that the presence of rock salt in the St. Clair formation, beneath Bay City, indicates other conditions than those of an open sea.

[‡] British Association for the Advancement of Science, 1844, pp. 155-169.

C. Traverse (Hamilton) Group.

§ 12. Name and geological position.

To the beds of soft shale and limestone, which lie conformably: beneath the St. Clair, the term Hamilton was applied by Winchell in his First Biennial Report. Later, to the same series, the name Little Traverse was applied by the same author. In 1895, Lane suggested the name Traverse alone, since the beds occur in the Grand Traverse as well as the Little Traverse region of Lake Michigan. Rominger used the name Hamilton in describing these Michigan beds and for their equivalents in Ohio the same was used by Newberry. For one member of the group, apparently the only representative in Ohio, Orton retains the name Olentangy shale, a name first suggested by N. H. Winchell for a bed of shale exposed in Delaware County. Hamilton has been very generally, if not uniformly, employed for this series by the Canadian geologists who have worked in the adjoining territory of Ontario. Whatever the name, all workers are agreed from the geological position of the beds, their lithological characters, and their numerous and beautifully preserved fossils, that they are the western representatives of the Hamilton of New York, lying between the Marcellus and Genesee shales.*

§ 13. General data.

An inspection of Plate I, shows that this group covers the northwestern corner of Dundee, nearly the whole of Milan and the northwest half of London townships. It enters from Lenawee County, extends northeastward as a belt from five to six miles wide and continues into Washtenaw and Wayne counties. Its apparent breadth is increased by the topography of its upper surface, for it and the St. Clair shales have been considerably eroded, as shown upon Plate VI. In the lower section, taken along the line of the Toledo and Ann Arbor railroad, at the left hand the Hamilton beds are designated as limestone and shale. They are seen to have been cut to a level below that of Lake Erie, which results in considerably increasing the breadth of the outcrop beneath the drift. The thickness of this overlying drift increases quite regularly, in consequence, from about 45 feet at the southeastern corner of Milan township, to about 150 feet, just southwest of the village. The actual elevation, above

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*I used the name Traverse to include Hamilton *and* Marcellus, and so did Winchell, in which usage it would be practically equivalent to Erian in the sense suggested by Clarke and Schuchert, L.

tide, of the surface varies from 636 feet in the northwestern part of Dundee township to 549 feet, where the drift is heaviest southwest of Milan. The dip of the beds is the same in direction and amount as that given for the St. Clair. There are no known exposures of these beds in this section of Michigan, or in any adjoining locality in either Ohio, or Ontario.

§ 14. Thickness.

From well records in northwestern Ohio and southeastern Michigan the Traverse group is known to be rather weakly developed, but to thicken to the north and east. The greatest development known in Ohio is but 20-30 feet according to Orton and in many regions it is not developed at all, the St. Clair then resting upon the underlying Dundee (Corniferous). In his map of the geology of the southern peninsula, published in 1876, Rominger does not represent the Hamilton at all in the southern portion of the state. In the deep well at Adrian there are 95 feet of limestone and shale which may properly be referred to the Traverse. At Ann Arbor, in the court-yard well, 70 feet of bluish limestone with some clay, were penetrated by the drill, probably without reaching the bottom of the series. This is regarded by Lane as Traverse, by Rominger as Upper Helderberg (Corniferous) and by Winchell as both, in part. At Royal Oak 215 feet of limestone and shale are referred to the Traverse. On the St. Clair river the total thickness is 300 feet. Eastward in Ontario, at Oil Springs, the group is 240 feet, at Petrolea 296 feet and at Kingstone's mills 396 feet in thickness. About Alpena it has increased to 600 feet, according to estimates of Rominger. Within the limits of Monroe County the bed has not been completely penetrated and we have no reliable data from which to determine its thickness. It is probably, however, not far from 100 feet, judging from the dip of the rocks and the apparent outcrop and surface topography of the beds. This estimate agrees also with the thickness found at Adrian.

§ 15. Lithological characters.

In the typical regions of west central New York the Hamilton beds consist of soft, bluish calcareous shales, with a few thin layers of bluish to gray limestones; the principal one of which is the so called "Encrinal limestone," scarcely more than a foot in thickness, but remarkably persistent. The shales break into coarse, lumpy fragments, not particularly fissile, never crisp and elastic as are the Genesee just above. When struck they seem dull and dead and when wet give a strong earthy odor and soapy feel. They readily soften into a blue clay when sufficiently exposed to the weather. These characters are always sufficient to readily distinguish the Hamilton shales from those of the Marcellus, Genesee and Portage. The Michigan representatives of these Hamilton beds seem to retain enough of these characters so that they may be separated from the St. Clair above and the Dundee beneath, even when their fossil contents cannot be procured. In southeastern Michigan and western Ontario there is a far greater development of limestone, at the expense of the shale, than in New York. Of the 95 feet in the Adrian well, according to the driller's log, 80 feet consisted of limestone, beneath which was 15 feet of black shale. In the Ann Arbor well referred to above, the 70 feet seems to have been largely limestone with the lower portions of the magnesian variety. Upon the St. Clair River the following section of the group occurs, as published by Lane in Vol. V, Michigan Geological Survey, Part II, (pp. 24-25).

Hard pyritiferous argillaceous limestone	2 feet.
Shale, "soapstone"	12 feet.
"Top limestone," often gaseous	80 feet.
Shale, "top soapstone"	150 feet.
"Middle limestone"	4 feet.
Shale, "lower soapstone"	65 feet.
"Bottom Limestone." (Corniferous.)	

A somewhat similar series of beds occurs about Petrolea, Ontario, of which the following represents the average section in thousands of wells:

Stiff blue boulder clay, drift	100 feet.
"Upper limestone," with little black shale at top	50 feet.
Bluish gray and drab shale, "soapstone" with few hard layers	120 feet.
"Middle limestone"	15 feet.
"Soapstone," with two or three hard beds	40 feet.
"Lower limestone" (Corniferous), giving oil at	45 and 135 feet.

The Traverse shales in Michigan are of the character ascribed to the typical Hamilton beds of New York, soft and bluish with a rather high percentage of lime carbonate. Certain layers may become much darkened, however, by bituminous matter. The limestones are typically bluish and argillaceous, but they may become darkened also. Fossils are exceedingly abundant in certain beds and beautifully preserved. The most common are various groups of the mollusca, corals, bryozoa and crinoids.

In the comparatively few wells sunk through the drift over the Traverse belt in Monroe County the description of the rock is very unsatisfactory. It is generally spoken of as hard or soft, as we might expect from the sections above given. From Milan to the southwestern corner of Sec. 18, Milan township, several records of a very hard rock having been first encountered were obtained. In the village of Milan, according to one driller, the rock is an "exceedingly hard quartz rock," according to a second it is a "hard sandstone." Records of sandstone (probably dolomite) were obtained at the southwestern corner of Sec. 18 at Stephen Olds and J. C. Miller's. Two other records of a similar rock were obtained in the northwest and southwest quarters of Sec. 7, London township. At Charles Sanford's N. W. ¼, S. W. ¼, Sec. 9, Milan a very hard rock was struck at a depth of 112 feet. This was so hard that only a few inches could be drilled each day and it was entered but eleven feet. Another hard rock was reported at the N. E. ¼, N. W ¼ of this same section. At the place of Samuel McMullen, N. E. ¼, N. E. ¼, Sec. 17, a well was put down to a depth of 309 feet, rock being struck at 95 to 100 feet. The rock was said to be "shell limerock, more or less honey-combed," and yielded no water. Limestone was also struck at the S. W. ¼, N. E. ¼ Sec. 22, at Patrick Nolan's, in his well 171 feet deep. Rock was struck at a depth of 112 feet, and at 150 feet what seemed to be sandstone. A strong flow of gas was obtained at a depth of 145 feet, was lighted and burned all one night. Mr. B. R. Ford reports limestone at the S. W. ¼, S. E. ¼, Sec. 14, in his 110 foot well. "Soft white rock," which might refer to a much softened limestone, or to a highly calcareous marly shale, was struck at a depth of 96 feet at the place of E. E. Spink, Sec. 26, N. W. ¼, N. W. ¼. Two records were obtained in this region which are much more suggestive of the typical Traverse shale. At a depth of 100 feet a "soapstone" was reached in the southeast quarter of Sec. 3, upon the place of Samuel Campbell. Thirty-five feet of this "blue soapy stuff" were entered. At Charles Campbell's N. W. ¼, S. W. ¼, Sec. 5, rock was reached at a depth of 142 to 143 feet. It is reported as a "soft mud rock, or soapstone." This was entered twenty feet when a "granite rock" was encountered. In the light of these facts it is difficult to predict the character of the bed which will be found beneath the drift at any given point within this Traverse area. The problem is complicated not only by the number of beds, of such varying character, but also by the topography of the rock surface.

§ 16. Lithological history.

During the time required for the accumulation and deposition of the marine sediments which form the Traverse beds, broad open sea conditions were changing to those which characterize the off shore. These changes took place in consequence of oscillations in the sea-bottom, causing the shore line to recede or advance; or in the amount and distribution of the fine detritus from the land, carried by waves and currents. When the mud deposition prevailed beds of clay were formed, which required only great pressure to become a shale. The presence of bituminous matter in sufficient quantity to color the deposit black or brown, indicates that the conditions had thus early been established which gave to the St. Clair shale its bituminous character. Conditions were favorable also for numerous forms of life which secrete lime carbonate from the sea-water and as their remains were covered by the deposits they were preserved entire, or after disintegration were mingled with the mud. During long periods the amount of mud was greatly diminished and in this clear open sea bryozoa, corals and crinoids flourished in abundance. Their remains accumulated, were cemented together with a calcareous slime and after being subjected to great pressure and some heat, were partially crystallized, forming the beds of limestone. If sandstone actually exists as is stated by the records given above, shore conditions must have prevailed temporarily and beds of sand accumulated, which were later cemented into compact rock, but probably there is no real sandstone.

D. Dundee Limestone.

§ 17. Name and geological position.

By this local name the present State Geological Survey designates the great limestone belt, which in Michigan, Ohio, and Ontario underlies the Traverse just described. It extends in all directions from southeastern Michigan and covers hundreds of thousands of square miles in the lake region, the Ohio and Mississippi valleys. It represents the upper member of a group of four, which are found well exposed in the Helderberg Mountains of eastern New York and to which group the name Upper Helderberg was given by the geologists of that state. Of this group the Caudagalli grit, Schoharie grit, and Onondaga limestone give out before reaching Michigan, while the Corniferous is the sole representative here. This was so named from the beds and nodules of hornstone which seem quite characteristic of it (*cornu*, a horn; *fero*, I bear), both in New York and Michigan. Newberry and the Canadian geologists generally have used the term Corniferous in referring to the limestone. A. Winchell and Orton have preferred Upper Helderberg, although the former in 1886,[*] includes the four New York members under the general term Corniferous Group, following Dana.[†]

Rominger in his report of 1876 uses Helderberg alone to include this Dundee and the underlying so called Monroe beds, but recognizes an upper and a lower division. By early geologists the Hamilton, Corniferous and Niagara limestone in the states to the south and west, were known collectively as the "Cliff limestone." In his state report for 1893,[‡] Hall proposes "Onondaga" for the two beds originally designated Onondaga and Corniferous, the hornstone being found distributed throughout the series. In view of this use of terms to designate the same bed of limestone, it seems wise to retain, in a report of this character, the local name given by the present survey.*

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[*] Geological Studies, p. 390.

[†] Two papers by N. H. Winchell before the American Association for the advancement of Science refer to the correlation of these limestones and may be summarized here. In 1873 (p. 100) a paper on the Devonian limestone in Ohio gives a section of five members, the bottom one, the Sylvania sandstone (?) being considered equivalent to the Oriskany. The two upper members are bluish and the author contrary to Newberry, would place them with the Hamilton, although they are colored Corniferous on the Ohio County maps. The third member is a light saccharoidal crinoidal limestone (our Dundee limestone?), and the fourth a vesicular or compact magnesian limestone (Monroe beds above the Sylvania?) often popularly mistaken for sandstone. In 1875 (part II p. 57) "On the Parallelism of Devonian Outcrops in Michigan and Ohio," he returns to the discussion of the border line between Hamilton and Corniferous, and shows how A. Winchell on paleontological grounds referred most of these Devonian limestones to the Hamilton, reducing the Corniferous to insignificant dimensions, while Newberry called them all Corniferous, and Worthen called the blue argillaceous limestones Hamilton (our Traverse), and the lower light colored assigned to the Corniferous. According to the author we have the following section from above:

1. Blue limestone.
2. Crystalline crinoidal limestone.
3. Arenaceous limestone.

The Water-lime of Ohio, beneath, has three different lithological aspects, to wit: thin bedded, fine grained drab, with distorted wavy bedding; harsh heavy bedded magnesian with wavy bituminous or carbonaceous films; in patches brecciated, this structure obliterating the true bedding and hardening the whole mass.

[‡] Thirteenth annual report of the State Geologist, Vol. I, 1894, 207.

§ 18. General data.

An inspection of the geological map of the county (Plate I), shows the Dundee beds striking northeast and southwest, forming a belt, varying in breadth from four to five miles? This enters, from Lenawee County, the northwestern part of Summerfield and the southwestern corner of Dundee townships, grazes Raisinville and forms the southeastern half of London and the northwestern half of Exeter townships, passing into Wayne County. Although conformable with the lower Traverse beds the general dip to the northwest is believed to be less than that given for the upper Traverse and lower St. Clair beds. It is probably from 20 to 25 feet to the mile upon an average, although locally it may be much more or much less. Mr. T. J. Brandt, foreman of the Christiancy quarry, on the Macon, for a number of years, estimates the dip in the 40 rods across as three feet, or twenty-four feet to the mile, and to be in the direction of W. N. W. In the Pulver quarry at Dundee it is much greater, being four and one-half feet in 200, or about 119 feet to the mile, and evidently local. The line of junction of the Dundee with the Monroe is believed to cut through Petersburg and very near Raisinville postoffice. At the latter place, however, the rock lies too deep to be reached by the river and there are no exposures in the bed for some distance upon either side, the river being through this region deep and sluggish. The highest surface elevation of the rock is at the county line, west of Petersburg, where it is 650 feet above tide level.

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* A rearrangement of the New York series has been recently proposed by Clarke and Schuchert in *Science*, December 15, 1899. (See also Amer. Geol. February, 1900.) The following portion includes the rocks described in this report:

System.		Group.	Stage.	Michigan equivalent.
Devonic..	Neodevonic.	Chautauquan.	Chemung beds.	
		Senecan.	Portage beds. Genesee shale. Tully limestone.	St. Clair shale.
	Mesodevonic.	Erian.	Hamilton beds. Marcellus shale.	Traverse group.
		Ulsterian.	Onondaga limestone. Schoharie grit. Esopus grit.	Dundee limestone.
	Paleodevonic.	Oriskanian.	Oriskany beds.	(hiatus?)
		Helderbergian.	Kingston beds. Becraft limestone. New Scotland beds. Coeymans limestone.	
Ontaric or Siluric	Neontaric or Cayugan		Manlius limestone. Rondout waterlime. Salina beds.	Monroe beds (?)

A more or less gradual fall occurs northeastward to the Wayne county line where it is not far from 580 feet, or 70 feet lower. From the river at Raisinville the contours (Plate I) indicate that there is a broad shallow trough in the bed, sloping northeastward, to be more fully described in another connection. (Chapter VI, § 2.)

§ 19. Drift covering.

The superficial covering of drift and soil does not exceed 70 feet and would average perhaps 35-40 feet, so that the bed lies much nearer the surface than the other two described. There are no natural outcrops although the beds are exposed in the bed of the Macon, northeast of Dundee and in the Raisin also. At Dundee the solid layers are exposed in the river just below the dam, but above it are covered by 2½ to 3 feet of sediment. In the western and southwestern portions of Dundee township the maximum covering occurs. At Petersburg slabs of Dundee limestone have been removed from the bank and assumed to have been *in place*, although the limestone in the bed of the river belongs to the Monroe. The junction of the Traverse and the Dundee in the southeastern part of Milan township is covered by about 45 feet of drift. Northeastward the bed has about the same amount of covering, which in the northwestern part of Exeter is increased to from 50 to 60 feet. It is very unfortunate that such valuable layers are so deeply buried and exposed only in the beds of streams where the problem of getting rid of the water is a very serious one.

§ 20. Thickness.

No complete section of the beds has ever been obtained within the limits of the county and its thickness can only be approximated. Judging from the dip and breadth of its supposed outcrop, beneath the drift, it cannot be far from 100 feet. In Ohio the maximum thickness is given as 75 to 100 feet. In the Adrian well the Dundee could not be differentiated from the Monroe. At Wyandotte and Trenton only a portion of the bed was penetrated, while at Detroit it was not entered at all. At Petrolea, Ontario, it is about 200 feet thick and at Alpena 120 feet. Winchell gives the formation at Mackinac a thickness of 275 feet but he included beds that are now known to belong to the next lower division.

§ 21. Lithological characters.

The Dundee is essentially a pure limestone formation with minor streaks and beds of an impure form of quartz, known as chert, the *hornstone* above referred to. The limestone varies in color from a light gray to brown, in some cases running into blue. The purer varieties show numerous cleavage faces of calcite and are heavily charged with fossils and their fragments. The argillaceous ingredient, so abundant in most of the Traverse limestones, is present in but small quantity, usually a small fraction of one per cent, but may run up to six to seven per cent in certain beds. A very small amount of iron is present (see analyses in Chapter IV, § 2), and the silica in the limestone varies from only a trace up to 9 or 10 per cent. Carbonate of magnesia is present in variable quantities in the various beds, some being remarkably free from it, while in others it may run up to 25 per cent. Analyses of the drill cores at the Sibley quarry show that the amount gradually increases toward the base of the series. The limestones always give a vigorous bubbling, (effervescence), with cold dilute hydrochloric acid when it is applied to the solid rock. Most of the beds have a strong oily odor and semi-fluid bituminous matter frequently collects in the cavities of fossils. At Petrolea this limestone series yields oil at 45 and at 135 feet.

In the Monroe County and Trenton quarries the upper beds are thin-bedded and shattered, probably due to the action of the great icesheet and later atmospheric agencies. Deeper layers may become heavily bedded, reaching a thickness of several feet. The same layer may be heavily bedded in the deeper portions of the quarry, but at its outcrop beneath the drift appears thin-bedded and much disrupted. Seams of clay very frequently separate the layers, washed in from the surface very probably by percolating water. Orton recognized in Ohio an upper and a lower division of the series. The upper division is more often blue, contains less chert and the beds seldom reach one foot in thickness. The lower is lighter colored, gray, drab and brown, contains more chert and the individual beds may reach a thickness of five feet. The Dundee is not sufficiently exposed in southeastern Michigan to say whether, or not, these divisions can also be recognized here. However, the characteristics of the lower division are all seen in the Dundee, Macon and Sibley quarries, while the upper half of the series is nowhere exposed.

In Michigan the Dundee forms the base of the great Devonian system, sharply separated by its fossil contents from the uppermost

Silurian beds, to be described in the next chapter, but with no evidence of any great structural break. The crustal movements which disturbed the Silurian beds in other sections of the world did not extend to Michigan, although the higher forms of life evolved as the result of such wide spread changes, promptly moved in. The spines and teeth of fishes are not infrequently found at the Sibley quarry, but the underlying Monroe beds have nowhere furnished any trace of a vertebrate. Lithologically the rocks are easily separated when specimens can be obtained, the Monroe limestones being of the dolomitic (magnesian) type and responding very slightly to cold dilute acid on the solid rock. In the drillers' log, however, it is impossible to separate them, and hence the desirability of saving samples of the beds penetrated.

[It is quite possible that there is more of a break between Dundee and Monroe, than appears stratigraphically in this county. In the table of formation equivalents, several appear to be omitted between them. Moreover beside the sudden paleontological difference there are conglomerates near the dividing line at St. Ignace. L.]

§ 22. Lithological history.

The relatively small amount of argillaceous and silicious matter in the limestones would indicate that their materials were accumulated far enough from the shore to escape the ordinary sediments which so largely made up the Traverse and St. Clair beds. Open but shallow sea conditions prevailed throughout the entire period and in the warm pure waters bryozoa, corals, crinoids and mollusks flourished in most wonderful profusion. Veritable coral reefs were formed over wide areas, many of the great colonies still standing where they grew, but imbedded in a matrix of fragments and calcareous slime, the result of wave action. Sharks of a strange type were numerous and contributed their spines and teeth after death. The floating vegetation had not yet, to any extent, invaded the sea, and this form of bituminous matter is absent. The oil which impregnates the rock was derived from the animal remains and was probably formed while the rock itself was in process of formation. Later the great pressure of superincumbent beds, with some heat, and the action of the carbon dioxide of the water compacted and partially crystallized the mass.

According to an estimate made by Dana, limestones due to coral accumulation alone, may gain one-sixteenth of an inch yearly, or five feet in 1,000 years. This growth he thinks is more rapid than when the limestone results from accumulation of shell remains. To have formed the 100 feet of Dundee limestone would then have required 20,000 years, upon the supposition that it took place at the maximum rate and that there were no periods of halt. While the organisms above referred to were secreting from the water the lime carbonate which it held in solution, other groups, such as diatoms, polycystines and sponges, were appropriating its silica and working it over into their hard supporting and protective structures. Their remains were finally added to the calcareous deposit and contributed to its supply of silica. The two foot bed of chert at the Sibley quarry shows equal quantities of lime carbonate and silica, from 43 to 44 per cent each, with nearly two per cent of magnesium carbonate and two per cent of alumina. The few fossils which it contains are all in silicified condition. It is not easy to satisfactorily account for the existence of such a bed, since it must have been formed before the limestone, just above it and subsequently to that of the bed just beneath. We cannot assume that the silica of the limestone beds was taken into solution and afterwards deposited, as in the case of nodules and veins of flint in the chalk beds. According to Maschke 100 parts of water, by weight, containing carbon dioxide, are capable of dissolving .078 parts of this amorphous silica. Or, stated differently, one cubic foot of such water is capable of dissolving .78 ounces of amorphous silica. According to Hunter sea water contains for each 100 vols. from .63 to 1.69 vols. of carbon dioxide gas. According to the researches of Buchanan sea water upon boiling will give off 2.3 vols. per 100 vols. and upon evaporation to dryness Jacobson found that twice this amount would be liberated. This gas is believed to be in some loose chemical combination since it is greatly in excess of what would be held by the water in response to the ordinary law for gas absorption by a liquid. Dittmar believed that there is practically no free carbon dioxide in the ocean water. The alkaline condition of sea water would enable it to dissolve somewhat more amorphous silica than would be due to the carbon dioxide alone. However, Dittmar, found in his analyses of samples of sea water gathered during the year 1873-6, by H. M. S. Challenger that there was a trace only of silica. If we assume the waters of this ancient sea to not differ essentially from those of today, except to have been saturated with silica, it would require a depth of about 3,000 feet of water to hold in solution the silica in the two foot bed of the Sibley quarry. If we assume that the chert bed was deposited as the result of the evaporation and concentration of the waters of an inland sea, it would require that the level be lowered about 3,000 feet. There is reason to think that this sea was comparatively shallow and becoming more so as time advanced.

Dittmar found that sea water is capable of becoming intensely alkaline, locally, through the agency of a limited amount of free carbon dioxide. In his experiments sea-water with an alkalinity expressed as 50.2 milligrams per liter, when saturated with carbon dioxide gas and digested for some time with calcium carbonate, shows an alkalinity of 314.2 milligrams. When magnesium carbonate is used, instead of the calcium, the alkalinity is increased to 1234 milligrams per liter. After being dissolved the magnesium carbonate and the sodium chloride suffer double decomposition with the formation of a carbonate of soda and a double chloride of sodium and magnesium. It is to the carbonate of soda that the greatly increased alkalinity is due and only a limited amount of the carbon dioxide gas is required since it is again returned in the reaction.

This increased alkalinity would enable the water to hold larger quantities of amorphous silica and if such silica were at hand it would be dissolved. This water upon being diluted, or having its alkalinity neutralized in part, would be compelled to deposit its silica and owing to the attraction which exists between molecules of the same substance, would tend to mass itself about the fragments of silicious organisms. In this way there would be produced an amorphous matrix with embedded fragments of organisms originally silicious. The few calcareous remains present would readily become silicified in such saturated water and we may readily imagine that while these conditions prevailed the bryozoa, corals and crinoids would be killed in the region affected, only a few hardy brachipods remaining, and the formation of limestone be temporarily suspended. The large amount of lime carbonate present in such finely divided state could have been precipitated directly or washed in by waves and currents from adjoining areas over which normal conditions prevailed. This explanation seems to fit best all the phenomena met with in the Dundee chert beds.

CHAPTER III.

SILURIAN FORMATIONS.

A. Monroe Beds.

§ 1. Name and geological position.

For this extensive series of beds, to which so many different names have been applied, it is convenient to have a definite local name. In his report published in 1861, A. Winchell describes the greater part of the series as the "Onondaga Salt Group" (pp. 57-60), but some of the lower beds exposed in the county, those at Stony Point and Point aux Peaux, he includes in the Devonian. In 1870 he recognized the latter beds as equivalent to the Waterlime division of the Lower Helderberg, of New York, *Leperditia alta* and *Spirifera modesta,* were found in the county, and on Put-in-Bay island *Eurypterus remipes.* Three years later a map was published showing the geology of the lower peninsula* upon which there is shown a narrow strip of Lower Helderberg, from three to four miles wide following the shore of Lake Erie. Narrow belts of the same are represented as surrounding the small patches of Onondaga, or Salina, at Ida and Ottawa Lake quarries. Newberry in 1873 describes these same beds as the Waterlime Group of the Helderberg formation of New York. He had accepted for the Upper Helderberg the name "Corniferous Group" and restricted Helderberg to what had been known eastward as the Lower Helderberg, made up typically of five divisions; the Waterlime, Lower Pentamerus limestone, Delthyris shaly limestone, Encrinal limestone and the Upper Pentamerus limestone, named in ascending order. The characteristic fossils of the Waterlime were collected and figured, *Eurypterus remipes* and *Leperditia alta.* Rominger, as previously stated, combined these with the Dundee, and applied to both the name Helderberg, but recognized an upper and a lower division, thus bringing this word back to something like its original meaning. The Sylvania sandstone he accepted, however, as the probable equivalent of the Oriskany, and hence places the break between his upper division, the Devonian, and the Upper Silurian at the top of this sandstone. It will be shown in this chapter that this break is really higher up and, consequently it lies considerably to the west in our geological map. In the later publications of the Ohio survey, Orton uses the term "Lower Helderberg or Waterlime Formation" and includes in it everything above the Niagara (considering that the Salina is not represented in the Ohio scale), and below his Upper Helderberg. It is exactly this series of beds which has been termed by Lane the Monroe beds. If the original New York Salina is really represented in the geological series of southeastern Michigan, as is very probable, there is no way yet of identifying its beds and separating them from the Waterlime division of the Lower Helderberg. The enormous beds of rock salt and gypsum which occur along the Detroit and St. Clair rivers would strongly suggest the Salina equivalency of these layers, but this cannot be positively asserted until we know the character of the limestones which overlie the Niagara. In Ohio the gypsum beds are underlain by several hundred feet of typical Waterlime dolomite and in New York the same thing occurs.

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*Michigan, 1873, extracted from Walling's Atlas.

In the later reports of the New York Survey* the Waterlime beds are taken from the Lower Helderberg and added to the Salina. If this practice is followed in this western region, and it has received Orton's sanction for Ohio, the discussion of the geological equivalency of the Monroe beds is simplified, since then they would all be referred to the Salina. In the rearrangement of the New York series by Clarke and Schuchert the Salina and the Waterlime are each recognized and constitute the two lower members of the Cayugan, or Neontaric.

§ 2. General data.

The remainder of Monroe County, eastward from the basal layers of the Dundee, is underlain by the upper beds of this great series. This comprises over two-thirds of the county and includes the entire townships of Whiteford, Bedford, Erie, La Salle, Monroe, Frenchtown and Berlin, nearly the whole of Ash, Raisinville, Ida and Summerfield and one-half of Exeter. It thus forms a belt from eleven to seventeen miles in breadth and extends further eastward beneath

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*Report State Geol., Vol. I. Geology, 1893.

Lake Erie and Detroit River. The beds strike northeastward as far as Stony Creek, where they turn eastward and, in the case of the lower beds exposed, finally southeastward. The dip of the beds varies considerably in direction and amount. Certain data indicate that from Toledo to Adrian this averages about 35 feet to the mile, but it is not regular, increasing in amount toward the west. This is shown by the narrowing of the outcrops of the beds beneath the drift in the southwestern part of the county and by the inclination of the strata seen in the quarries just over the Ohio line. The upper layers from the county line northwest of Ottawa Lake to Adrian dip at the rate of 56 to 57 feet to the mile. Measured upon the Trenton, which may be assumed to be conformable with the overlying beds, the dip from Monroe to Dundee is about 26 feet to the mile. From Monroe northward the direction of the dip changes from northwest to north and, as nearly as can be made out from the interpretation of the well records at Trenton and Wyandotte, equals 30 to 40 feet to the mile. The breadth of the outcropping belts, beneath the drift, is increased in the northeastern part of the county because of the increased thickness of the beds, and in spite of this greater dip. The Monroe beds lie nearer the surface than any of the preceding formations and are responsible for all the actual natural outcrops. The heaviest covering of drift occurs in the southeastern portion of Erie township, where it is from 90 to 100 feet thick. At the head of Ottawa Lake the highest elevation of the rock surface is attained, about 685 feet above sea level. From this point there is a very gradual slope of the rock surface in all directions, being greatest in rate and amount toward the southeast. In the southeastern corner of Erie township the elevation is about 470 to 480 feet, having dropped over 200 feet in 15 miles, or at an average rate of 13.3 feet to the mile. An inspection of the contours upon Plate I shows, however, that the slope is much steeper over the latter half of this distance, being equal to about 24 feet to the mile.

§ 3. Thickness.

The great breadth of the outcrops beneath the drift, of the Monroe beds indicates that we have a much thicker formation than any previously described. In Ohio the total thickness is 600 feet and borings in Michigan and Ontario indicate that it increases toward the north for a certain distance. In the five Trenton wells the average thickness is 1216 and in the Dundee well it is over 1000 feet. At

Wyandotte, in the well of the Eureka Iron and Steel Works the thickness appears to be 1375 feet. In the Solvay wells, at Delray, it is apparent that none of this thickness has been lost and it may have been considerably increased. Still further north, at Goderich, Ontario, according to Hunt, some 1517 feet of these beds were penetrated without reaching the bottom. Upon Plate V is recorded the section of one of the Monroe deep wells reprinted from Vol. V, which shows that the Niagara was reached at a depth of 700 feet. From the breadth of the outcropping layers and the dip it is estimated that about 200 feet of these beds are represented between Monroe and the base of the Dundee, so that the entire thickness of these beds in the middle of the county is not less than 900 feet. From what has been said, however, and from an inspection of the geological map, it will be apparent that the actual thickness to be penetrated in any given boring will depend upon its north and south position in the county and its distance southeastward from the base of the Dundee.

§ 4. Lithological characters.

So far as they are exposed within the county the Monroe beds consist of a series of gray to drab magnesian limestone (dolomite), embedded in which are strata of oölite, very sandy dolomite, and a friable bed of remarkably pure sandrock. These beds are so distinct, lithologically, that they have been of much service in the deciphering of the geological structure of the county and each will be separately described as fully as its importance seems to warrant. In the following chapter IV on quarries a still more detailed description will be given of the individual beds that make up the series. In general, it may be said that the typical dolomite layers show the normal proportions of lime carbonate and magnesium carbonate; from 50 to 55% of the former and 42 to 43% of the latter ingredient. The amount of alumina and iron together is generally less than one per cent, while the silica, in *insoluble* form, varies greatly at the expense of the carbonates. Bituminous matter is present locally but does not impregnate the rock as in the case of the Dundee. Near the top of the series, where weathered, the rocks become of almost a chalky whiteness and contain gypsum, but ordinarily they are gray to dark drab, sometimes running into a yellowish brown. In the deeper portions of the quarries they are sometimes blue. The rock responds only slightly to cold dilute acid, unless it is powdered, when the effervesence is brisk. In this way the Monroe dolomite is to be distinguished from the Dundee limestone. Fossils are not abundant in the dolomite, except rarely in patches, and they are always in the form of molds, internal or external casts.

The rock layers are generally thin-bedded, rarely reaching one foot and usually less. Toward the lake, near Monroe, the beds have been much disturbed and the rocks shattered. In the Plum Creek quarry of the Detroit Stone and Supply Company, the bedding is described as being almost vertical, but could not be directly observed owing to the water present. North about two miles in the quarry of the Monroe Stone Company, the bedding is typical but the rocks seem shattered. In Monroe there is a tradition that about thirty years ago, one Sabbath morning, an explosion occurred in the bed of the river just above the city, which startled the entire region and very visibly disturbed the layers of rock in the river bed. There is wide-spread evidence that at a much earlier period than the time of the disturbances above referred to, probably while the beds were forming the rocks which compose them were broken into angular fragments and then recemented. Such brecciated beds are seen near Monroe and at Stony Point, and, according to Rominger, Orton, and Winchell, occur all over northwestern Ohio, the islands of Lake Erie, at Goderich and on the island of Mackinac. Thin slabs of dolomite showing ripple-marks and mud cracks occur in the Plum Creek quarries, characterize the Ohio beds, and extend into eastern New York. Immense concretionary bodies with finely laminated structure, regarded by Winchell at the time of the preparation of his first report as organic in their nature, are seen about Monroe and to the northeast. Their great convex surfaces bulge upwards through the floor of the quarry north of Monroe (See Plate IV); they are seen eastward on the lake shore, and are still better shown in the Patrick quarry on Grosse Isle, where they seem to be 12 to 15 feet in diameter in certain cases. It is very probable that they were formed while the dolomitic slime was still soft, through the action of the concretionary agencies which are as yet so little understood.

In the beds underlying Monroe and known only through samples of the well drillings, the dolomites are found to contain varying quantities of a form of calcium sulphate, known as anhydrite. Northward this mineral is found in distinct beds many feet in thickness and associated with pure rock salt, shales and sandstones. The section of the Noble well, at Monroe, as given on Plate V, shows a 230 foot bed of yellowish limestone, briskly effervescing with dilute acid, which was struck at a depth of 100 feet from the surface, or about 300 feet from the base of the Dundee. This seems to correspond in position with a group of limestones, 276 feet in thickness, containing corals, chert, and dolomite beds, reported by Hunt as occurring at Goderich, at the foot of Lake Huron. The series was struck at a depth of 357 feet from the surface and is overlain by 278 feet of dolomite, with thin limestone layers.* Hunt regarded this as an intercalation of Corniferous (Dundee) amongst the beds of Lower Helderberg (Monroe). The overlying dolomite was supposed to be continuous with the Lake Erie beds containing Waterlime fossils. The limestone itself is of the gray non-magnesian variety, rich in fossils, corals and chert. From fragments in the cores Hall identified *Favosites Winchelli* Rom., and *Favosites Emmonsii*, Hall, these being characteristically Devonian. This peculiar limestone series is underlain by dolomite containing gypsum.

§ 5. Lithological history.

It is evident from the variety of rock material represented as making up the extensive Monroe series that its formation must have taken place under widely varying conditions. The sea bottom was subject to repeated oscillations and the shore line advanced and receded, probably several times. Geologically it was a period of unrest, these disturbances in Michigan being but distant ripples from the agitation which brought the Silurian to a close and caused the advance in plant and animal life. The beds of sandrock and the conglomerate of Ohio and Mackinac were formed while shore conditions prevailed. The beds of shale, which occur toward the bottom of the series, represent the muddy accumulations of the off-shore. The beds of dolomite, which comprise the main bulk of the series in southeastern Michigan, seem to have been formed in a shallow, open sea, sufficiently distant from land not to get much sand and mud.† The paucity of fossil remains in such beds led Cordier, Hunt, Ramsey and others, to assign to them a chemical origin. If such a theory is accepted in whole, or in part, then this dolomite *dough* must be regarded as a chemical precipitate, to be described below. The oscillations of the earth's crust occasionally exposed patches of this sea-bottom to the air and sun, which upon drying shrank and gave the mud cracks mentioned as occurring about Monroe, as well as elsewhere. These were later submerged, covered with soft slime and indefinitely preserved. Pressure, carbon dioxide gas and probably a low degree of heat have compacted these soft layers into firm rock.

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*Geological Survey of Canada, Report of Progress, 1876-77, pp. 221-243.

†Or the climate may have been dry and the land low and the sea shallow so that not much sediment was formed. L.

The conversion of calcium carbonate into the double carbonate of calcium and magnesium, known as dolomite, has as yet received no entirely satisfactory explanation. The geological occurrence of dolomite gives no warrant for the theory of Von Buch that it represents limestone, in which some of the calcium has been replaced by magnesium, through the agency of magnesia vapors rising from beneath. Neither can it be maintained that thousands of square miles of heavily bedded dolomite have resulted from the action of percolating spring waters carrying magnesium salts in solution. Still less probable is the theory that the dolomitization is due to the action of molten magmas from the interior of the earth which have come in contact with limestone beds. In sea water there occur considerable quantities of magnesium chloride (10.878 parts) and magnesium sulphate (4.323 parts), in every 100 parts of the total salts, according to the analyses of Dittmar. By experiment it has been found that these salts, under high pressure, and above the boiling point of water, can convert limestone into genuine dolomite. An analysis of coralline limestone from the elevated coral island Matia, one of the Society group, according to Dana (Corals and Coral Islands, 1872, p. 357), gave 38.07% of magnesium carbonate, showing it to be in reality dolomite. Ordinary coral contains from 95 to 98% of calcium carbonate, with only a slight amount of magnesium carbonate. Dana concludes that this introduction of magnesium into the composition of the coral has taken place apparently in the sea water at ordinary temperatures and without the agency of any mineral waters except those of the ocean. "But the sand or mud may have been that of a contracting and evaporating lagoon, in which the magnesian and other salts of the ocean were in a concentrated state." These conclusions of Dana are accepted by Neumayr* and probably represent the consensus of geological opinion at the present time.

October 28th, 1844, Cordier deposited with the French Academy of Sciences a sealed packet, which after his death was opened and found to contain a paper entitled "De l'origine des roches calcaires qui n'appartiennent pas au sol primordial."[*] In this the chemical origin of the great bulk of our limestones and dolomites is maintained, the carbonates being derived from the reaction of carbonate of soda upon the chlorides of calcium and magnesium in sea water. The supply of sodium carbonate he believed to be derived from the decomposition of feldspars, from alkaline springs and from plutonic emanations. Some three years before this information was made public, Hunt had published an elaborate account of his experiments on salts of lime and magnesio,[†] under the title "On Some Reactions of the Salts of Lime and Magnesia, and on the Formation of Gypsums and Magnesian Rocks," in which he had arrived at about the same conclusions. The source of the carbonate of soda, in all cases, he considered to be decomposing feldspathic minerals of the sedimentary rocks and the argillaceous beds are the correlatives of the limestones. The conclusion reached in this paper (p. 383) is that

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*Erdgeschichte, 1886, p. 590.

> "Dolomites, magnesites and magnesian marls, have had their origin in sediments of magnesian carbonate formed by the evaporation of solutions of bicarbonate of magnesia. These solutions have been produced by the action of bicarbonate of lime upon solutions of sulphate of magnesia, in which case gypsum is a subsidiary product; or by the decomposition of solutions of sulphate or chloride of magnesium by the waters of rivers or springs containing bicarbonate of soda. The subsequent action of heat upon such magnesian sediments, either alone or mingled with carbonate of lime, has changed them into magnesite or dolomite."

Hunt insists that calcium chloride must be absent, whatever the reaction, and that isolated and evaporating basins are indispensable conditions for the formation and deposition of magnesian carbonate.[‡] An analysis of waters from the equivalent of these Monroe beds, in Western Ontario, at Chatham, Petrolea and Bothwell shows them to be derived from a bittern, "the result of the evaporation of the waters of an ancient sea."

One of the most recent discussions of the question is contributed by Dr. E. Philippi, of Berlin, in a paper entitled, "Ueber einen Dolomitisirungs vorgang an südalpinen Conchodondolomit."[§] The author believes that dolomites in many instances, at least, result from a *leaching* of a lime rock which already contains a certain quantity of magnesium carbonate. The theory is based upon the supposition that the carbonate of lime is more readily dissolved than the carbonate of magnesium, and hence that under proper conditions more of the former would be removed. The result of this would be to produce a rock which would show relatively greater and greater quantities of magnesia until the normal proportion of lime and magnesia might be attained. There is no reason to think that this theory can have any application in the case of our Monroe beds, where 900 to 1,000 feet of practically horizontal layers are evenly dolomitized. It would necessitate the destruction of unsupposably great masses of limestone, unless there is assumed to be present, from the first, considerable quantities of the magnesium carbonate. If such supposition is made then the difficulty of accounting for this carbonate is as great as is that of the original question. In ordinary corals which contribute so largely to the formation of limestones, there is present but a very small quantity of magnesia, *Isis hippuris* yielding Forchhammer the relatively large amount of 6.36%. Upon the supposition, however, that the magnesium carbonate is but one-tenth as soluble as the calcium carbonate, it is evident that in the process of leaching such a stone, the magnesium would have practically disappeared before the normal proportions for the two had been attained. There is no apparent agreement upon the part of supposed authorities however, in regard to the relative solubility of these two carbonates. Bischof found that a prolonged action of water, charged with carbonic acid, upon a limestone containing 11.54% of magnesium carbonate, dissolved out 4.29% of its calcium carbonate, but without appreciably affecting the magnesium.* With water containing three to four grams of magnesium sulphate to the liter, Hunt found that there would be dissolved 1.2 grams of carbonate of lime and 1 gram of carbonate of magnesia to the liter.

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[*] C. R., Feb. 1862, pp. 293 to 299.

[†] American Journal of Science, 2d series, Vol. XXVIII, 1859, pp. 170-187, 365-383.

[‡] Chemical and Geological Essays, 1891, p. 92.

[§] Neues Johrbuch für Mineralogie, Geologie und Palæontologie, I Band, Erstes Heft, 1899, pages 32 to 46.

From his researches Dittmar concluded that in sea water carbonate of magnesia is far more freely soluble than is carbonate of lime. In all the above cases the water contained different ingredients but nothing which might not be present in the waters percolating through a bed of limestone. Additional evidence against the application of this leaching process to our Monroe beds is furnished by the complete conversion into dolomite of the granules of the bed of oölite. These were originally calcareous and, judging from the Great Salt Lake oölite now in process of formation, have not been appreciably reduced in size. There has taken place here a partial replacement of the calcium carbonate with the carbonate of magnesium, this action occurring at the time of the formation of the beds and in sea water strongly charged with magnesium salts.

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*Lehrbuch, Vol. II, p. 1176. See also Treadwell and Reuter in Zeits. für Anorganische Chemie, Vol. XVII, 1898, pp. 170-204.

It seems necessary to conclude from these and still other considerations that a great inland basin had been formed in which the waters were greatly concentrated, while the open sea retained its normal composition. Hunt explains the intercalation of Corniferous amongst the beds of the Salina, by assuming that in the ocean the life had advanced into the Corniferous age, while that in the basin itself was still Silurian. A temporary influx of the sea into a part of this basin would bring in the higher forms and establish a new set of conditions, favorable for the growth of corals and the production of limestone. The cutting off of the direct supply from the ocean would in time exterminate the life in this particular region and by the opening of direct communication with the remaining interior basins, former and older geological and palæontological conditions would again prevail. Such basins would supply the necessary conditions for the deposition of gypsum, or anhydrite, and for the formation of rock salt found further north. Through the continued concentration of the water contained, after the point of saturation had been passed, there would be deposited a layer of calcium carbonate followed by one of calcium sulphate and later one of rock salt.* As evaporation progressed the water would be withdrawn from the margins of the basin and the deposits of salt would not extend shoreward as far as those of the lime carbonate and calcium sulphate. For this reason we find beneath Monroe more or less anhydrite, but no rock salt until we pass further north, in which direction numerous beds are developed, some of them attaining surprising thickness beneath Detroit. The deeper portions of the original evaporating basin then lay to the north of Monroe county, and the shore to the south. After the deposition of most of the calcium carbonate, calcium sulphate and salt there would remain in the central and deeper portions of the basin a solution, rich in chlorides of calcium, magnesium and sodium, and consequently intensely bitter to the taste. If complete evaporation took place these salts would crystallize, but if not the bittern containing them would impregnate thoroughly the beds formed later. Percolating waters would subsequently take up these salts again and give rise to the highly charged mineral waters that characterize the central portions of this great Silurian basin.

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*See Vol. V, Geol. Survey of Mich., Pt. II, pp. ix to xix. "The origin of Salt, Gypsum and Petroleum," Lucius L. Hubbard.

Description of special beds.

§ 6. Sylvania sandstone.

On account of their economic and stratigraphic importance it seems desirable to describe somewhat in detail two sets of strata which mark well defined horizons in the beds of dolomite. The chief characteristics of the latter rock will be presented in the following chapter IV upon quarries. Of these included beds the thickest, most important and most readily recognized one is the Sylvania sandstone.

This has been named from its occurrence southwest of the village of Sylvania, Ohio, where it has been quarried for the manufacture of glass. It enters the southwestern corner of Whiteford township (Sec. 5, T. 9 S., R. 6 E.) as a narrow belt scarcely more than one-half mile in breadth, owing to its steep westerly dip. It strikes northeastward across the county, broadening gradually to about four miles near the center, as seen upon the map (Plate I). Toward the Raisin, northeastward across Raisinville, the bed seems to narrow to less than a couple of miles as far as southwestern Ash, then turns to the east and maintains a breadth of two to three miles across Ash and Berlin townships. Upon entering Whiteford, from Ohio, it is covered by twenty to twenty-two feet of surface materials, which are reduced to ten feet, or less, in Sec. 28. Drift fragments of the harder portions of the rock occur in the vicinity, scattered over the fields, in the N. E. ¼, S. E. ¼, Sec. 5; N. E. ¼, N. E. ¼, Sec. 32; N. E. ¼, N. W. ¼, Sec. 33 and in the N. W. ¼, N. E. ¼, Sec. 29. From Sec. 28 the drift covering increases northeastward to twenty and then to thirty feet or more. In Raisinville the rock comes nearer the surface and forms the bed of the Raisin for a considerable distance. At the ford, near Grape, heavy building blocks for foundation walls have been removed. Where the rock is less coherent it has been scooped out by the river and only the harder strata appear in the ledges exposed during stages of low water. Just below the ford between claims 494 and 408 (South River Raisin), there is a bed of brown dolomite capped by six to ten inches of chert, while at the ford itself, blocks of sandstone were found which are either in place or have been shifted but a short distance. Opposite claim 275 (South River Raisin) dolomitic sand rock occurs.

The only natural outcrop of this sandstone occurs in the southwest quarter of Sec. 2, T. 6 S., R 8 E. (Claims 493, 484, North River Raisin.) Here extending over an area of eight to ten acres, to the north and west of the "Blue Bush Cemetery" the rock is directly exposed or covered by only a few inches of soil. Beneath an area of sixty acres the surface covering is said to be but two to three feet in thickness. Several pits have been opened exposing the bed to a depth of 12 to 30 feet, from which sand has been taken for shipment. In the eastern part of Ida township a trough is developed in the upper surface of this soft bed, extending its entire distance northeastward, as shown by the contours on the map (Plate I). The drift covering over the deeper portions of this trough in Ash and Berlin varies from 30 to 35 feet. The highest elevation attained by the bed is 673 feet above sea-level in Secs. 28 and 32 of Whiteford. The drop is gradual in the direction of the strike, giving an altitude of 610 feet A. T., in Ida, 613 to 588 A. T. in Raisinville and, finally, in Berlin a minimum of 560 feet A. T., or 13 feet below the level of Lake Erie.

Where it enters from Ohio the bed is probably not over 30 feet in thickness, but it increases gradually toward the northeast. At the cranberry marsh of Mr. C. W. Everett (S. E. ¼, Sec. 24, Summerfield) it showed a thickness of "40 to 50 feet," overlain by thirty feet of blue limerock (dolomite). In the deep well at Ida (N. E. ¼, Sec. 3) there were 45 feet penetrated. The breadth of the outcrop along the Raisin would indicate about the same thickness. The greater breadth of the belt in eastern Ida, western La Salle and southern Raisinville, does not seem to be due to increased thickness but rather to the position of the beds. At the sand pits, above referred to, three sets of cores have been taken out, giving a thickness of about 60 feet. There is a capping of four feet of a laminated dolomite here, which has escaped the general erosive agencies, showing that practically the entire thickness is represented by these cores. To the northwest, about three miles, at the Woolmith quarry (S. E. ¼, Sec. 29, Exeter), borings give the bed a thickness of 50 feet. The bed was penetrated at Gibraltar, Horse Island, in a 130 foot well belonging to Edmund Hall, but the record of the thickness could not be obtained. It is a matter of geological, if not economic interest, to know that this bed continues northward giving a thickness of 95 feet at Trenton, 130 feet at Wyandotte and, in the ten Solvay wells at Delray, an average of 99.4 feet.

Beds of essentially similar sandrock, but carrying considerable dolomitic matrix, occur both above and below the main bed, but separated from it by layers of dolomite. These secondary layers may be mistaken for the Sylvania proper, as was done by Rominger, and its thickness underestimated.* In the Davis quarry one and one-half miles west of the village of Ida (N. E. ¼, Sec. 4), a series of drill cores gives a compact white sandrock six feet thick, at a depth of 25 to 31 feet. Beneath this lies a silicious dolomite which caps the main bed struck at Ida. At the Lulu quarry (N. W. ¼, Sec. 16, Ida) one foot of similar sandrock is exposed with dolomite above and below. The same rock is seen in the floor of the Cummins' quarry (S. E. ¼, Sec. 2, Whiteford). At the mouth of Willow Run a layer of sandrock occurs which might easily be mistaken for the Sylvania, except that it is much coarser than the typical sandstone. It is overlain and underlain by beds of silicious dolomite, as seen in the Raisin bed and as indicated by adjoining well records.

Owing to the limited number of natural exposures the tracing of the Sylvania across the county had to be done largely from records of farmers and drillers. Such records were not always as abundant and definite as was desired and the breadth of the outcrop beneath the drift can be regarded as only an approximate one. Certain common expressions were found to characterize the bed in these records collected and much importance attached to them. The loose sand so frequently pumped from the wells over this belt was said to resemble "snow," "flour," "salt," "granulated sugar." The bed itself furnishes water throughout its extent and a very common report was that a thin crust of the bed had only to be punctured, when the water could be pumped or would rise to the surface. In numerous instances the sand-pump had to be used first before any considerable quantity of water could be obtained, thus testifying to the incoherent nature of the bed. Except in a few deep wells the bed is not entered far, so that we have comparatively few records of its thickness. In such cases it is said to cut the drill very badly, so that it would require very frequent sharpening. The reason for this will be apparent when the form of the individual grains is described. Some typical descriptions will serve as samples of the data, by means of which the bed was located upon the geological map.

Information secured from Barney Gay, a local driller of South Rockwood. At John Strong's S. E. ¼, Sec. 8, Berlin, struck 15 feet of sand, "white as snow," went five feet in five minutes, and pumped sand for two weeks. At the blacksmith shop in the village, at a depth of 18 feet, "struck a funny kind of stuff," which was white. From all the wells in the neighborhood he secures white sand. Sometimes it has above it a hard crust. At the place of Joseph Borrow (S. E. ¼, S. E. ¼, Sec. 17, Berlin) it is twenty-four feet to a "shell-like rock," below which the drill drops four to six inches. This rock is a dark lead color. Before water will flow there must first be pumped out a snow-white sand of which there may be two to two and one-half feet. Has pumped out two to three wagon-loads. At Peter Donelly's (S. E. ¼, N. E. ¼, Sec. 19, Berlin) it is 32 feet to rock. Dug 14 feet and drilled 16 to 18, when the drill dropped three to four inches. The water rose into the dug portion and "spewed" white sand, covering the bottom to a depth of several inches.

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*Geol. Survey of Mich., Vol. III, Pt. I, pp. 27-29.

Charles G. Peters, S. W. ¼, Sec. 8, Berlin (T. 5 S., R. 10 E.). Has two flowing wells, each 28 feet to a "shell-rock." In the well at the house the drilling was stopped for the night, no water having been secured. The next morning the water was found to be flowing, having brought up eight to ten bushels of sand, "white as paper," and giving the appearance of a snow bank about the mouth of the well. In the well in the woods he did not secure this sand, although a gray variety was struck. At the N. E. ¼, N. E. ¼, Sec. 18, Berlin, he put down a well in which rock was struck at 30 feet and entered 32 feet. It wore the drill considerably. In color it was "grayish, or dark like, whiter on drying." Considerable sand had to be pumped out, when the well flowed until a well was drilled at Howard Valrance's (N. E. ¼, Sec. 17, Berlin), since which time the water has had to be pumped. Still another well was put down in S. E. ¼, S. E. ¼, Sec. 7, Berlin (T. 5 S., R. 10 E.), at which place rock was struck at 30 feet. A very hard shell was first reached upon which the drill "rang like a kettle," and beneath this lay the same sandrock.

Charles M. Hood, N. W. ¼, S. W. ¼, Sec. 13, Ash. Here it is 32 feet to rock. Water rises to within four feet of the surface, is hard and contains iron. Just below the clay a hard "crust," a few inches thick, is struck. This has only to be punched through and the sand pump put in to secure water. From this well there have been pumped several wagon boxes of sand, which is used for scouring. When wet it packs very firmly. Has put down wells at eight different places in the neighborhood in each of which this same sand was obtained.

C. B. Loranger, N. W. ¼, Sec. 26, Berlin. Flowing well of sulphur water, with some iron and, at times, oil. After entering rock two feet a white sand was reached, looking "like flour." A few rods east is another well from which much sand has been pumped.

Augustus Dobberstein, S. W. ¼, N. W. ¼, Sec. 29, Ash., 35 to 36 feet to a very hard rock. Water stands 10 to 12 feet from surface and is considered "soft." A barrel of the water will sometimes yield a half barrel of white sand. This sand cut the drill badly and filled in the hole so as to prevent further drilling. Well becomes completely filled with sand and has to be reopened.

Peter Stumm, N. W. ¼, N. W. ¼, Sec. 32, Ash. 32 feet to a solid rock, above which water was secured. There was a "soft stuff" just above rock, which felt gritty on the augur. Jabbed through a crust two to three inches thick, when water rose rapidly in the well, standing about seven feet from the surface. The drill was cut badly and upon entering the rock "bounced."

Michael Strobel, N. E. ¼, Sec. 15, Ida. Rock was reached at 27 to 28 feet and entered 20 feet. An attempt to take out a core failed. No casing was put in and the hole filled with sand.

The chief characteristics of the Sylvania sandstone will be inferred from the above records. Typically it is a fine grained, sparkling, snow-white sandrock of remarkable purity. Usually it is very friable and incoherent, readily crumbling into sand in the fingers, or under the action of a drill. This is due to the lack of cementing material present with which to bind together the grains. Locally, considerable dolomitic cement may be present, forming a compact white sandstone, from which good cores may be removed by means of the "diamond drill." The beds exhibit only coarse stratification as observed at the pits and along the Raisin. At the Sylvania quarries, however, in some of the beds, there is quite a distinct lamination seen on weathered surfaces. Fossils are rare and very poorly preserved for the most part. Fragments of the sandstone taken from the Raisin near Grape furnished traces of trilobites, corals, brachiopods, lamellibranchs and gasteropods, but in an unsatisfactory condition for positive identification. At the outcrop the upper strata, to a depth of 8 to 10 feet, are discolored by percolating surface water. The stain is said to be due to organic matter, however, and not to iron. The following analysis of the rock at this locality is kindly furnished by W. H. Cowles, of Detroit, and shows the composition before it has been subjected to the washing process which prepares it for glass manufacture:

Silica	96.50%
Calcium carbonate	1.50
Magnesium carbonate	1.04
Iron oxide	.00
Sulphuric acid loss and undetermined	.76
Loss on ignition	.20
	100.00

Under the low-power of the compound microscope the individual grains, instead of being rounded, exhibit sharp points and edges, with plane faces. A close inspection shows that a very large proportion of them are, in reality, short hexagonal prisms, terminated at one or both ends with a hexagonal pyramid. They are thus more or less perfect quartz crystals. Examined with polarized light, a still more interesting fact is developed. The body of each minute crystal is an ordinary rounded sand grain, about which a thin shell of quartz has crystallized so as to give it optical continuity; as is evidenced by the fact that both granule and shell extinguish simultaneously, when revolved between crossed nicols. In the central granule Prof. C. H. Smyth, Jr., has identified crystalline inclusions of hornblende, apatite, tourmaline, rutile and zircon. Fluid inclusions, with bubbles, can also be seen with high power, showing that these grains do not differ from ordinary sand grains of the sea or lake shore. Upon the outside of the crystals are developed sparingly, minute rhombohedrons of calcite, or dolomite, probably judging from analysis above, the latter.

Perfect quartz crystals from the insoluble residues of limestones had been described in the early part of the century but their real nature remained unknown for many years. In 1880 Sorby described such sand grains as consisting of an angular or rounded quartz grain, with a secondary addition of crystallized silica, giving crystalline continuity.* In the New Red Sandstone of Penrith, he found upon the surface of the enlarged grains impressions due to the interference of contiguous grains. "Thus proving conclusively that the deposition of crystalline quartz took place after the nuclei were deposited as a bed of normal sand." (p. 63). In the case of the Vosges sand Daubrée had recognized such enlarged grains and believed them due to the local action of heated water. In the Fifth Annual Report of the Director of the U. S. Geol Survey,* Irving describes and figures similarly enlarged grains from our American rocks, showing that the secondary silica may serve as a cement and give rise to quartzites from sandstone. His investigations prove

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*Quarterly Jour., Geological Society, Vol. 36, p. 62.

> "That most if not all of the ancient quartzites, as well as many of the quartziferous schists, are simply fragmental rocks composed in the main of the original fragmental material—unaltered save by some of the ordinary metasomatic processes—cemented together by a siliceous cement of secondary origin. This siliceous cement forms the only part of the rock that has crystallized *in situ*, the more or less intricate interlocking of its areas and its common optical continuity with the original quartz fragments giving rise to the deceptive appearance of complete original crystallization" (p. 221).

The discussion of the secondary enlargement of quartz grains was continued by Wethered in 1888,† and theories of their origin presented. He concludes that they cannot represent detrital matter, since there is no evidence of wave action, that they could not have crystallized directly from a solution of silica and that they are not the result of crystallization of amorphous or chalcedonic silica, but that they do represent additions of crystalline silica to a rolled or broken quartz crystal. This secondary silica he regarded as having been

> "extracted from solution by the molecular affinity between the silica of the detrital quartz and the silica in solution" (p. 196).

With the results of these investigations in mind let us frame an explanation of the formation of this rather remarkable bed of sandstone. The stratification noted would prove that it was originally deposited in water, and the presence of marine forms in fossilized condition, proves that this water was the sea. Sand accumulates only in the region of the shore.‡ To account for the spreading of a shore deposit over such wide areas it is necessary to assume that the shore line was not stationary, that it was advancing landward, owing to subsidence, thus establishing shore conditions successively over wider and wider areas. Branner describes a beach deposit in Brazil, consisting of cobbles, pebbles and sand and attaining a thickness of ten feet, which was thus made to cover thousands of square miles.* In this case, however, an elevation was in progress and the deposit attained only the ordinary thickness of beach material. The gradual subsidence of the sea bottom in southeastern Michigan, while the materials for the formation of the bed were accumulating, would permit a considerable increase in thickness. The lower strata would contain coarser particles, deposited while the shore was nearer; the upper strata would consist only of grains which were small enough to be carried some distance seaward by waves and currents. The silica for the sand grains was probably derived indirectly from the ordinary crystalline rocks and the grains were rounded and assorted by wave action. The mud was carried seaward and there should exist somewhere a bed of shale, the correlative of the Sylvania sandstone unless it was derived from the disintegration let us say of the Potsdam sandstone. Dolomitic slime derived from the disintegration of calcareous organisms, or precipitated directly from the sea water as previously explained, might be deposited with the sand grains and serve as a matrix. The proportion of sand and slime would determine whether there would be formed a dolomitic sandrock or sandy dolomite, such as underlie and overlie the Sylvania proper. Finally, when the shore line had sufficiently retreated the supply of sand would fail, only the formation of dolomite would continue and the epoch of the Sylvania would have closed. Subsequent to the complete formation of the bed, percolating waters, rich in alkaline salts and holding relatively larger quantities of silica in solution, saturated the loose sand, and about each grain a thin layer of crystallized quartz was deposited, owing to the "molecular affinity between the silica of the detrital quartz and the silica in solution." Experiments upon fragments of crystals suspended in saturated solutions of the same substance have shown that the crystalline accessions invariably yield crystalline, and hence optical, continuity with the original fragments. The molecules of the secondary silica simply dropped back into the places occupied by those lost from the original crystal fragments from which the sand grains were fashioned. The character of the percolating water soon changed, otherwise there would have been formed a quartzite as soon as the silica deposited began to firmly unite the grains. That the secondary enlargement of the grains took place after the formation of the beds is conclusively proven by an examination of those embedded in the adjoining dolomites. When fragments of these are digested in hot acid in order to remove the carbonates, the sand thus obtained is snow white and, under the microscope, shows also secondary additions of crystallized silica. Instead of getting perfect crystals, however, the surfaces are seen to be roughened with imprints of rhombohedrons of minute dolomite crystals, against which the crystals of quartz have grown.

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*1885, pp. 181 to 242.

†Quart. Jour., Geol. Soc., Vol. 44, pp. 186 to 199.

‡i. e. in the littoral belt, but sand as fine as that of Sylvania may be carried a good way by currents. L.

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*"The supposed Glaciation of Brazil." Journal of Geology, Vol. I, No. 8, 1893, pp. 753-772.

The upper strata of the Sylvania sandstone, to the north of the Raisin, are about 70 feet below the base of the Dundee, this space being occupied by dolomites, more or less silicious, which cannot be separated lithologically, or palæontologically, from those lying beneath. The quarry rock at Ottawa Lake, the "sinks," Lulu, Ida, Raisinville and Woolmith, is all derived from these beds which intervene between the Sylvania and the Dundee. Thus embedded in the Monroe beds there is no reason yet known for assigning to it any different geological age than that of these Monroe beds themselves. At the time of the Newberry survey of Ohio the Sylvania was supposed to separate the Lower from the Upper Helderberg formations, and with an entire absence of fossils, it was very naturally correlated with the Oriskany sandstone of New York. Rominger regarded it as occupying this same geological position in our Michigan series and its correlation with the Oriskany as very probable. In his Biennial Report of 1860 and in his map of 1873, Winchell includes the bed in the Corniferous. In 1893 Orton first pointed out the fact that this bed in Ohio is overlain by typical Waterlime strata[*] said to be 200 feet in thickness. These beds are seen in the Sylvania quarries, lying to the west of the sand pits, and one mile farther north at the Cooper quarry, N. E. ¼, N. E. ¼, Sec. 18, T. 9 S., R. 6 E. The Sylvania sandstone must be regarded as part of the Waterlime group of the Salina.

§ 7. Oölitic beds.

Several beds of dolomitic oölite are known to occur, embedded in the dolomitic limestone. The upper one lies about 45 feet above the top of the Sylvania and hence about 25 feet below the base of the Dundee. It varies in thickness from three and one-half to four feet, as seen at the Woolmith quarry and in the adjoining excavation on the place of John Hoffman. The lowest bed exposed lies below the Sylvania at a distance of about 100 feet and in the neighborhood of 200 feet below the Dundee, giving a well defined horizon. This bed is most typically developed on Plum and Stony creeks as a light brown absorbent stone, gritty to the feel and showing a thickness of twenty inches to two feet. To the southwest of Monroe the structure becomes somewhat modified and obliterated and grades into a bed of brown dolomite, five to six feet in thickness, known locally as "bastard limestone."

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[*] Geol. Surv. of Ohio, Vol. VII, pp. 17-18. The correlation of this part of the geologic column is just now a subject of lively controversy. See two recent papers by H. S. Williams, pp. 333-346, and Charles Schuchert, pp. 241-332, of Vol. XI, Bull. Geol. Soc. of America.

Occupying the crest of the ridge it has been found in enough places in the county to permit the approximate tracing of it upon the geological map, whereas this was impractical for the uppermost bed. It enters the county from Ohio in Sec. 4, Whiteford (T. 9 S., R. 6 E.) and is first seen in the N. E. ¼, N. E. ¼, at a small quarry belonging to Stephen Young. Passing northeastward it is seen in the excavation along the roadside belonging to Nelson Bush (S. W. ¼, S. E. ¼, Sec. 25, Whiteford) and again some 80 rods eastward on Halfway Creek. It is next seen in the quarries about Little Lake in Bedford township. The best exposure is in the quarry on the farm of Mrs. White, where it is overlain by a few inches of loose dolomite. Upon the Dunbar farm to the northwest (S. W. ¼, S. W. ¼, Sec. 10, Bedford), the oölite is struck in a small field quarry about 100 yards east of the residence. At the center of Sec. 32, La Salle township, it was found in a small quarry belonging to W. W. Green, and again upon Otter Creek, claim 538, South River Raisin, where it is much compacted, light brown in color, having a gritty feel and might easily be mistaken for a sandstone. Still striking northeastward it appears in the bed of Tamarack Creek (property of Dennis Navarre, claim 498), and on the south bank of Plum Creek, claims 498 and 230, South River Raisin, in the Navarre quarries. The dip here is local and equals about six to seven feet in one hundred. Some 200 yards up the creek local flexures bring the bed to the surface, where the dip is 4° toward N. 22° W. At Brest, on Stony Creek, property of Mrs. Mary Emerson (claim 532, North Stony Creek), the oölite occurs in the best condition for study. The granules are very generally spherical and readily separate from one another in the fingers. From this point the bed strikes eastward and curves to the southeast, where it forms a submerged layer at Stony Point, Lake Erie. The gravelly beach from Stony Point to Point aux Peaux contains many partially worn fragments of this bed.

As seen on Stony Creek the component grains of the oölite are very regularly spherical and average about one-fiftieth of an inch (0.4 millimeter) in diameter. The cementing material is dolomite, which has formed a thin layer over the granules, showing minute crystal faces when examined with the magnifier. These granules have a concentric structure, being made up of a series of delicate, concentric, spherical shells. Occasionally when the granules are broken across some of their central layers drop out, giving them the appearance of having possessed a nucleus of some different material. With cold, dilute hydrochloric acid they effervesce slowly at first, but as they fall to pieces, the action becomes more rapid. When a considerable number are thus dissolved the acid becomes clouded and there settles to the bottom a dark brown, bituminous sediment. When single granules are treated with strong acid upon a glass slide, under the microscope they are seen to disintegrate into an immense number of minute, irregular dolomitic crystals, which dissolve only very slowly. There remains behind only the brownish slime and a few irregular birefractive fragments, none of which can, however, be regarded as a nucleus about which the concentric shells could have formed. In thin sections there is no trace of a solid nucleus, such as a sand grain, although the central portion sometimes appears darker and sharply defined from the remainder of the granule. These darker centers are more frequent in the Plum Creek sections than those from other localities from which material was sectioned and are apparently due to an accumulation of bituminous matter. Their diameter varies from one-sixth to three-fourths of that of the granule itself. Occasionally the central portion is lighter colored by transmitted light and a band of darker material lies outside, while in some instances a light band intervenes between the darker central portion and an outer darker band. In the preparation of the thin sections the central portion has occasionally dropped out, showing a surface of weakness between certain layers. When magnified the granules are seen to be made up of a great number of interlocking birefractive crystals of dolomite, which become well defined rhombohedrons, with their curved faces, about the outside surfaces of the grains. Toward the centers the crystals are invariably smaller. Except for this difference in color and size of the component crystals there is a very little trace of concentric structure when viewed with the microscope. Where the central mass has dropped out the margin appears rough.

Rarely dolomite crystals are arranged as a single concentric layer. There is no trace of a radial arrangement of the crystalline particles in any of the sections.

As has been stated the oölite shows considerable modification in its various outcrops and, indeed, considerable at the same locality. Typically it is made up of an immense number of subspherical bodies, cemented more or less firmly, and having the appearance of a mass of fish eggs, from which it derives its name. Upon Plum Creek these corpuscles are smaller than those seen at Brest, and the structure is not so apparent to the naked eye. Under the hand magnifier the darker central core is very conspicuous in all those which happen to be broken across near the center. Mingled sparingly with these spherical to ellipsoidal bodies are others which have about the same, or somewhat less, diameter but with a length of two to three diameters and are either straight or slightly curved. Their ends are rounded and they have the appearance of short, blunt sticks. Except for this difference in shape and bulk they exactly resemble the other bodies. At the White quarry, Little Lake, the granules are nearly all flattened and elongated to a length of about two diameters, while at the Dunbar quarry near by, the flattened forms are abundant with large numbers of the small subspherical type filling the spaces. The central darker core, with the outer lighter shell, gives evidence of the same structure as that described above. Under the microscope, in thin sections, they exactly resemble the structure of the more nearly spherical forms and they behave similarly with the acid. Still a third type of structure occurs in the oölitic rock, shown most beautifully and typically at Stony Creek and in the Dunbar bed, where it comprises nearly fifty per cent of the rock. These are flattened, tongue-like masses, varying much in size, from that of the flattened granules above mentioned to heavy masses four inches long, by three wide and one inch thick. Ordinarily their thickness varies from one to two millimeters, but their length and breadth are more variable, usually falling within five to ten millimeters. They are arranged in the rock with their flat faces approximately parallel with one another and with the bedding. They usually show evidence of having been broken into fragments and partially recemented, testifying to the disturbances which gave rise to the breccia in the adjoining beds and to the fact that they were *brittle* when the disturbances occurred. Their edges and corners are rounded, their surfaces somewhat undulating frequently showing rounded tubercles and irregular ridges. The smaller the bodies the more irregular and tubercular they become, unless, indeed, there are several types of these to be distinguished. Two hand specimens collected from Stony Creek and one from Bush's quarry, in Whiteford, show the portion of the bed sampled to be made up almost exclusively of this kind of material. These forms might easily be mistaken for frondescent *Stromatoporoids* or *Bryozoa*, so far as their external appearance is concerned, but in thin section they reveal none of the structure of these groups. Dissolved in acid they yield considerable bituminous sediment. Under the microscope they are seen to consist of a dense, interlocking mass of birefractive dolomite crystals, sometimes stained more or less toward the center.

It is evident that these three types of structures were all deposited simultaneously. It is very probable that they were *formed* simultaneously and not far from where they now occur. From their similarity in structure and composition and from their tendency to run together through intermediate forms, it is very probable that they were all formed by the same, or related agencies. The stratification of the bed and its gradual passage into dolomite, with marine fossils, shows that the accumulation took place in the sea. From the discussion which has preceded, it must be inferred that this sea was an inland one and rich in chlorides of sodium, magnesium and calcium. Any explanation of the formation of one form should, obviously, account for the formation of the others. The commonly accepted theory for the origin of the subspherical bodies of a typical oölite, viz., sand grains held in suspension by currents in a solution saturated with calcium carbonate, from which there are deposited concentric layers, will not apply here. In the first place there are no such foreign nuclei present and in the second, this explanation could not apply to the elongated and frondescent bodies. Through the kindness of Prof. I. C. Russell we have had an opportunity to examine some oölitic sand now forming about the shore of Great Salt Lake, and have found it surprisingly similar to our Monroe county product. It is made up of subspherical granules very largely, which average in size the same as those of our Plum Creek material, but ranging as large as those noted from Stony Creek. They are grayish white in color, consist of calcium carbonate, and show a darker central core with a lighter outer band when broken open. Occasionally they are stained with blue or red coloring matter. Exteriorly they are smooth and polished, the larger ones looking like porcelain. Mingled with these bodies are numerous stick like forms, straight or slightly curved, with rounded ends, looking like magnified *bacilli*. Their diameter is less than that of the average subspherical forms, about equals that of the smaller, while the length ranges from two to five or six diameters. These have the same composition and external appearance as the others, including the occasional staining. Much less frequently than the rods, there occur irregular flattened masses, considerably larger than the other forms, with rounded edges and corners and carrying upon their broader surfaces small "tubercles." These are very similar to the structures so abundant at Stony Creek and at Little Lake and Bush's quarry. In the Great Salt Lake oölitic sand none of the larger mases described are represented in the samples. It is possible that these are present in the water of the lake but are not cast upon the shore by the waves, or only the smaller forms of this type may be forming. When dilute acid is applied to any of these bodies the effervescence is very rapid and the layers of calcium carbonate are quickly dissolved, leaving behind what appears as a nucleus in each case. An examination of this with the microscope shows a whitish, porous, brittle mass, having the general form of the spheroid or rod from which it was derived. The material shows no double refraction and refuses to be acted upon by even strong acid. About it there appears to be more or less slime with fragments of irregular crystalline fragments. In some cases a relatively good sized, rounded, quartz grain occurs. If we can assume that the nuclear body is organic, that the crystalline particles are not essential but only incidentally or accidentally present; then the Salt Lake oölite is practically identical with that of our Monroe county bed and they have both been formed under the same conditions and by the same agencies. In the latter granules we find the same crystalline fragments, but the organic structure is represented by only the bituminous matter and there is no apparent nucleus upon digestion with acid.

In the fall of 1891 Dr. A. Rothpletz, of Munich, visited the shore of Great Salt Lake and made an examination of the conditions under which the oölite is forming. He found that which had not yet been washed up from the shore bottom to be partly covered with a bluish-green mass of algæ in which he recognized colonies of *Glœocapsa* and *Glœthece.** These forms secrete large quantities of calcium carbonate in form of rounded tubercles, which are often massed together in larger irregular tubercular masses, inclosing dead alga-cells. In dissolving the oölitic granules of the beach in very dilute acid he was able to identify the dead and crumpled *Glœocapsa* cells. The rods and tubercular masses yielded similar cells, the former more abundantly than the oölitic grains. He concludes that

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*Botanisches Centralblatt, Nr. 35, 1892. Translation in American Geologist, Vol. X, No. 6, 1892, pp. 279-282.

"The oölites of the Great Salt Lake are, therefore, indubitably the product of lime secreting fission-algæ, and their formation is proceeding day by day. * * * According to the present stage of my researches, I am inclined to believe that at least the majority of the marine calcareous oölites with regular zonal and radial structure are of plant origin, the product of microscopically small algæ of very low rank, capable of secreting lime."

In the case of the Woolmith bed of oölite the smaller components are much compacted and their structure nearly or quite obliterated. There is a light chocolate colored, dolomitic matrix in which they show as minute whitish points and streaks. The frondescent structures are abundant, arranged parallel to the bedding and with their creamy white color give a streaked and blotched effect to the rock. Locally it has been termed "liver rock." These structures are more abundant towards the upper part of the bed and occur more sparingly in the lower portions. A laminated layer at the top furnishes a transition from the oölite to the overlying dolomite. In the case of all the oölitic beds we must assume that the material was originally calcium carbonate and that it was altered to the dolomite, through the action of magnesium salts in a concentrated solution of sea water. Favorable conditions for the formation of these beds and their conversion into dolomite were several times established. A bed somewhat similar to that of the Woolmith quarry, but which seems to be situated at a lower horizon, is seen in the Rath quarries, claim 685, South River Raisin.

B. Beds Reached by Borings.

§ 8. Deep well records.

Ten deep wells have penetrated the Monroe series of rocks to a greater or less depth. Upon Pl. V there is shown graphically the beds beneath the city of Monroe, so far as they have been revealed by the driller's record and samples. A complete series of such samples was examined by A. C. Lane and the data upon the right side of the plate determined, from which the geological identifications were made. Aside from the 210 feet of limestone previously referred to as a possible interpolation of Upper Helderberg (Corniferous), there is seen to be a series of variously colored dolomites, with or without anhydrite, down to a depth of 700 feet.* These are all referred to the series of Monroe beds the base of which is at an actual elevation of about 110 feet below sea-level. This same series of beds was penetrated to a depth of 910 feet in the Newport well, situated in the N. E. ¼, S. W. ¼, Sec. 1, Berlin, (T. 6 S., R. 9 E.) upon the estate of C. H. Buhl. The elevation of the mouth of the well, as determined by the aneroid barometer, is 585 feet. Overlying the rock is three feet of a rusty pebbly clay. The following data were determined from a study of the drillings which averaged one sample for every twenty feet. Throughout the series there occurred rusty grains which stained the neighboring fragments. Occasionally one of these showed weak magnetism but usually were unaffected by the magnet. These are believed to represent oxidized fragments of the drill.

Newport Well Record.

0 to 3 feet.	Rusty pebbly clay.
3 to 83 feet.	Drab dolomite, giving considerable muddy sediment upon being dissolved in acid. Fragments of calcite in thin crusts and considerable anhydrite.
83 to 93 feet.	Light drab dolomite, with mingled dark shaly fragments. Considerable muddy sediment. Anhydrite and sand grains present.
93 to 165 feet.	Samples not saved.
165 to 195 feet.	Drab dolomite with carbonaceous flakes, which burn with flame. Cold dilute acid acts quite energetically upon the fine drillings. Anhydrite and sand grains present.
195 to 220 feet.	Bluish-drab dolomite, drillings much compacted in vial. Anhydrite is present. Flow of fresh water secured at this level.
220 to 247 feet.	Very similar to last, but rather more anhydrite and drillings more firmly cemented together.

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*For records of the three wells see Vol. V, Part II, pp. 69-70, and Vol. III, Part I, pp. 30 to 31, and below p. 74. The well recorded in Plate V is known as the Moore well.

247 to 305 feet.	Samples are wanting.
305 to 315 feet.	Bluish-gray dolomite, carrying anhydrite and some selenite. Much sediment left after dissolving in acid. Further flow of fresh water.
315 to 372 feet.	Bluish-gray, argillaceous dolomite. Some anhydrite present throughout.
372 to 420 feet.	Buff dolomite which leaves much yellow sediment after dissolving. The insoluble portion contains numerous rounded grains of quartz, some hornblende and some black non-magnetic grains, which are probably some form of titanic iron oxide. The rock also carries anhydrite.
420 to 435 feet.	Bluish dolomite. Drillings are coarse and very firmly compacted in vial, as though set with mortar. Lumps of anhydrite are mingled with the fragments of dolomite.
435 to 448 feet.	Quite similar to the bed 372 to 420 feet. Drillings are fine and looser as contrasted with the beds just above and just below. Much anhydrite is present.
448 to 467 feet.	Practically identical with bed 420 to 435 feet. A bluish dolomite, drillings coarse and firmly cemented in vial. Anhydrite is present in lumps.
467 to 500 feet.	Bluish, dolomitic shale. Action of cold dilute acid upon solid lumps is weak; brisk on heating for a comparatively short time leaving behind much bluish, muddy sediment. Drillings not compacted. Some anhydrite is present.
500 to 520 feet.	Bluish-drab, argillaceous dolomite. Drillings not compacted in vial. Lumps of anhydrite occur and black flakes.
520 to 560 feet.	Bluish, dolomitic shale, essentially similar to that occurring from 467 to 500 feet. Fragments of anhydrite mingled with those of the shale.
560 to 598 feet.	Blue and drab dolomite. Drillings are fine and considerably compacted in the vials. Fragments of anhydrite.
598 to 615 feet.	Drab to gray dolomite. Anhydrite and some sand grains. Lower portion of bed is more impure.

615 to 720 feet.	Drab to gray dolomite, with varying amounts of anhydrite. Some of the samples of drillings compacted in vials.
720 to 815 feet.	The five samples from this bed are all alike and more buffish than those from above bed. The rock is a dolomite also, containing seams of carbonaceous matter, fragments of anhydrite and scales of selenite. For some reason the rusty iron grains are exceedingly abundant in all the samples.
815 to 825 feet.	Drillings have a gray color and under the magnifier look much like pure anhydrite. With heated acid, however there is considerable effervescence showing the presence of the carbonates of calcium and magnesium in large percentage. The rusty grains are not quite so abundant, but are numerous.
825 to 833 feet.	The drillings from this bed are a purer white than above. In hot acid they effervesce vigorously for a short time only, leaving behind much anhydrite, which dissolves slowly and quietly.
833 to 844 feet.	Gray to dray dolomite with fragments of anhydrite and scales of selenite.
844 to 860 feet.	Samples missing.
860 to 910 feet.	Bluish gray dolomite. Drillings relatively coarse and somewhat compacted, containing bluish flakes and fragments of anhydrite.

We may assume that the Monroe beds lying between the base of the Sylvania sandstone and the Plum Creek oölite have not materially thickened in passing northward this short distance and that the thickness equals about one hundred feet. The breadth of the outcrop of this belt, measured from Brest and to the west of Newport, is about five miles, giving an approximate depth of twenty feet to the mile to these beds. Noting the position of the Monroe and Newport wells, with reference to the oölite, it will be seen that the shaly dolomite, struck in the former well at a depth of 390 feet, corresponds very closely in position to the similar rock in the Newport well reached at a depth of 467 feet, and that this is presumably the equivalent in the Ohio scale of the Tymochtee slate (§ 9). The upper belt of shaly rock in the Monroe section is also represented in the Newport series but runs into the portion of the well from which samples were not saved. The supposed interpolation of the Corniferous (Dundee) should be found in the Newport well at about 157 to 387 feet. There is, however no trace of it here, the beds seem to be dolomitic and all contain anhydrite, so far as we may judge from the nine samples.

Three deep wells have been put down within the county of which it has been impossible to secure the record or any samples of the drillings. Just before the oil and gas excitement about Toledo, a party leased land of Oliver S. Bond, Toledo, Ohio, for the purpose of putting down a test well. This was located on the S. W. ¼, S. W. ¼, Sec. 29, Bedford, one mile south of Lambertville. The well is supposed to have reached a depth of 500 feet, where it was suddenly terminated by the withdrawal of the machinery for use in the Toledo field. During the latter part of the summer and the fall of 1896 a test well was drilled in the extreme northeastern corner of Sec. 33, Berlin, (T. 5 S., R. 10 E.) upon land belonging to John Frey. The work was done under the direction of E. E. Harris, of Detroit, from whom it was impossible to secure any data. The well is supposed to have reached a depth of 1300 to 1400 feet and according to newspaper reports, penetrated a bed of rock salt at about 1200 feet. The latest and most successful well within the county was drilled in November and December, 1898, upon the land of F. C. Potter, two miles southeast of Vienna. The well is located in the N. W. ¼, N. W. ¼, Sec. 22, Erie township and its mouth is about four feet above Lake Erie level. The Trenton limestone was reached at 1555 feet and penetrated 112 feet, making the total depth of the well 1667 feet. The yield of oil and gas from this well will be given in another connection, (Chapter VIII, § 9).

Somewhat fuller data were secured concerning the Ida deep well, upon the property of Simeon Van Akin N. E. ¼, N. E. ¼, Sec. 3. This was drilled during the summer of 1893 by George M. Brown, Bowling Green, Ohio; George M. Barnes, Toledo; and Simeon Van Akin, of Ada; contractor, M. E. O'Conner, Cygnet, Ohio. The elevation of the mouth of the well is about 640 feet above mean tide level. A pipe was driven twenty-two feet to the rock when the drilling began. Ten feet of "common limerock" were found to overlie forty-five feet of Sylvania sandstone. Gray limestone (dolomite) followed to a depth of 320 feet from the surface, when a light bluish shale was struck, this constituting the "first break." The well passed through this "slate" and entered a "limestone" darker in color than the overlying beds. At about 480 feet the water "boiled as in a kettle" owing to the escape of gas. This was found to burn but had to be extinguished in order to prevent injury to the derrick. For a distance of sixty feet into the rock the flow of gas increased. At 700 feet a "light colored rock" was struck and found to be 100 feet thick. A handful of the drillings was saved by Mr. Van Akin and a sample submitted to a Chicago chemist, D. W. Chapman, who pronounced the material magnesium sulphate (epsomite) a very soluble substance, known as "epsom salts" and nowhere known to form beds of such thickness. It was stated to have been formed from the "oxydation of sulphuret of iron to a sulphate by the action of water and the decomposition of a bed of dolomite by the iron sulphate." A sample of the same substance was secured from Mr. Van Akin by the writer and it, indeed, proves to be magnesium sulphate. In its geological position in the Monroe series this bed corresponds to a one hundred foot bed of light colored dolomite carrying much anhydrite, which is shown upon Plate V, as occurring beneath Monroe at a depth of 500 to 600 feet. It is very probable that this is the equivalent of the Ida bed and that the sample of the epsomite collected just happened to come from a dry cavity in the dolomite, in which places the salt is occasionally found as an incrustation. The total depth of the well was 1200 feet when the drilling was suddenly stopped.

In the western part of the county two wells have been drilled to the Trenton limestone, each of which proved unsatisfactory so far as oil and gas are concerned. The first was drilled in 1887 in the old Christiancy quarry, upon the Macon, then owned by a Mr. R. H. Nogard. Owing to the secrecy maintained in regard to the results, it was inferred that the well had proven a success and a second one was drilled by citizens of Dundee the following summer (1888) upon the place of Alfred Wilkerson, one mile south of the village. Samples of the drillings are not available but the driller's logs are kindly furnished by Byron J. Corbin, of Dundee. They are valuable only as they enable one to infer the real nature of the beds.

Driller's record, Nogard well.*

Location, N. W. ¼, N. W. ¼, Sec. 8, T. 6 S., R. 7 E. Elevation of mouth, 660 feet.

Formations.	Thickness.	Depth of top from surface.	Elevation of top above tide.
Gray limestone	59	0	660
Buff and white limestone	100	59	601
Blue limestone	150	159	501
Buff and blue limestone	260	309	351
Oil limestone	100	569	91
Buff limestone and brown marble	600	669	−9
Oil limestone	151	1,269	—609
Snow white marble	100	1,420	—760
Red, white and blue marble	400	1,520	—860
Shale	30	1,920	—1,260
Gray, black and brown slate	200	1,950	—1,290
Trenton limestone		2,150	—1,490

Total depth, 2150 feet.

Driller's record, Dundee well. (Sparks and Allen, Elgin, Ill.)

Location N. E. ¼, N. E. ¼, Sec. 25, T. 6 S., R. 6 E. Elevation of mouth, 680 feet.

Correlations by Lane.	Formations.	Thickness.	Depth of upper surface.	Elevation of upper surface.
	Quicksand	8	0	680
Pleistocene.	Clay	30	8	672
	Gray oil limestone	65	38	642
	Sulphur limestone	70	103	577
	Dark limestone	20	173	507
	Fine gray sandstone (Gas)	12	193	487
	Blue gray limestone	30	205	475
Waterlime	Gray sandstone	18	235	445
	Fine limestone	105	253	427
	Hard shell limestone	40	358	322
	White sandstone	7	398	282
and	Dark limestone	48	405	275
	Hard shell limestone	45	453	227
	White putty limestone	70	498	182
Salina.	White putty limestone, very hard	50	568	112
	Buff limestone	220	618	62
	Alternating blue, gray and brown limestone	315	838	—158
	Fine buff limestone	10	1,153	—473
	Gray limestone	7	1,163	—483
	Buff limestone	23	1,170	—490
	Light gray marble	15	1,193	—513
(Guelph dolomite.)	Snow white marble	135	1,208	—528
Niagara.	Dark blue marble	80	1,343	—663
	Red marble	15	1,423	—743
	Pinkish gray marble	35	1,438	—758
(Rochester shale.)	Blue slate	30	1,473	—793
	Gray limestone (Mineral water)	60	1,503	—823
Medina.	Red slate	60	1,563	—883
Hudson River.	Gray slate	100	1,623	—943
	Blue slate	110	1,723	—1,043
Utica.	Brown slate	300	1,833	—1,153
Trenton.	....	....	2,133	—1,453

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*Mr. C. S. Nims, the driller, told Mr. Lane that there was 1,640 feet of 4 to 5 inch casing to the "slates" and from 600 to 800 feet of them, the latter including probably the Medina, Lorraine and Utica shales. These figures agree better with those of the Dundee well. A tube of samples of the latter was kept, and shows selenite, but was shaken up. The record of the Dundee well was given in the Dundee Reporter, Dec. 7 and 21, 1888, and Jan. 11 and 21, 1889.

Entered Trenton 144 feet securing oil and gas in small quantities, both of which disappeared and no more water was secured. Total depth of well 2277 feet.

§ 9. Interpretation of records.

In addition to the 200 feet which comprise the upper part of the Monroe series and which are exposed in various parts of the county, there are about 700 feet in the vicinity of Monroe which are known only through these deep well records. As stated in previous sections the thickness is less towards the Ohio line and increases northward. These beds consist of variously colored dolomites, some carrying considerable quantities of anhydrite. At 390 and 450 feet of the Monroe section the dolomite contains some shale, which is very probably the horizon of the "Tymochtee Slate," of N. H. Winchell. This was described and named in the geology of Wyandot county.[*] In his report of 1893,[†] Orton calls attention to this bed as one of the few recognizable horizons in the Ohio scale and states that it occurs below the middle of the series and probably within one hundred to two hundred feet of the base. At Monroe the bed itself has thickened from the twenty-four feet found in the typical Ohio locality and its lower layers lie from two hundred to two hundred and fifty feet from the base of the series. The shale reported in the Ida well at a depth of 320 feet is too high up for the Tymochtee and seems to correspond with those shaly beds which comprise the upper part of the Monroe section.

Beneath the Monroe beds in southeastern Michigan there lies a compact, rather homogeneous mass of dolomitic limestone known as the Niagara or Guelph. This is typically fine grained, very light colored and free from anhydrite and salt, apparently formed in the open sea before the concentration of the sea-waters had begun which characterized the succeeding age. The Monroe section shows about 360 feet of this formation, which near its middle portion becomes arenaceous. In Ohio the lowest member of the Niagara is a light colored shale, with thin calcareous bands. In the Wyandotte well[‡] ten feet of "slate" are regarded by Lane as the equivalent of the Niagara (Rochester) shale. Below the Niagara lies a bed of greenish and reddish shale, about one hundred feet in thickness, to be referred to the Medina of the New York series. These colored shales pass into the bluish Hudson River (Lorraine) calcareous shales which show a thickness in the Monroe section of 400 feet. In southern Ohio the Hudson River consists of alternating layers of blue limestone and blue shale. Northward the amount of limestone diminishes so that it is all liable to be classed as shale in well records. According to Orton it also grows darker in color and difficult to separate from the underlying Utica. Towards the Ohio line the thickness becomes less, reaching in northwestern Ohio 300 feet. The Utica consists of a mass of brown bituminous shale, becoming black towards its base. Its thickness seems to be about 160 feet beneath Monroe. Part of the 300 feet assigned to the Utica in the correlation of the Dundee well belongs to the Hudson. Finally comes the coveted Trenton, the deepest bed yet reached by the drill in this portion of the state. At Toledo the top of the formation is struck at about 812 feet below mean tide level. In the Potter well near Vienna its elevation is 978 feet below tide. In the three Monroe wells the Trenton was found to be lower toward the west or northwest. In the Moore well, third ward, the elevation is—1154 feet; in the Long well, 2d ward, it is —1149 and at the brick yard in the west part of the city it was found to be —1160. The average of these three gives —1154 feet. In the Dundee well the elevation was stated to be —1452 feet and —1490 in the Nogard well. These data give a drop in the Trenton from Toledo to Monroe of seventeen feet to the mile and from Monroe towards Dundee of about 26 feet per mile. These beds are all known in outcrop to the south, in Ohio, and northward about the shores of lakes Michigan and Huron. In southern Ohio the Trenton consists of heavy beds of true limestone with interstratifications of shale. Towards the north the shale becomes less and the rock passes into a true buff colored dolomite in which condition it enters Michigan. From the general dip of the Trenton it is apparent that Monroe county is located on the western slope of the great Cincinnati anticline.

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[*] Survey of Ohio, Vol. I, 1873, page 638.

[†] Survey of Ohio, Vol. VII, page 16.

[‡] Geol. Sur. of Mich., Vol. V, Pl. LXVI.

CHAPTER IV.

QUARRIES.

A. Dundee Formation.

§ 1. Macon quarry.

This bed has long been known as the "Christiancy quarry," from the early owner, Judge I. P. Christiancy, formerly of Monroe. It is now owned by B. E. Bullock, of Toledo, Ohio. It is located in the former bed of the Macon River, from which the water has been deflected by an embankment, and extends for a distance of about thirty rods along the stream, with a main excavation of 450 by 200 feet. This is the most promising locality in the county for a high grade limestone, since the same beds are here exposed as at the now famous Sibley quarry, near Trenton. The quarry lies two miles northeast of Dundee, one-eighth mile from the Detroit and Lima Northern R. R. and three-fourths of a mile from the Ann Arbor Railroad. The nearness of the Macon interferes now with the quarrying of the deeper and heavier beds, but with an extension of the quarry northward, in which direction the stripping increases only slowly, the annoyance caused from the water would be gradually diminished. At present the water is pumped from the deeper portions of the quarry and drains slowly into the abandoned Nogard well. It thus seems likely that the deepening of the quarry will open up subterranean passages through which the quarry may be perfectly drained.

Four beds may be recognized in the quarry which may be designated as A, B, C and D in descending order. Bed A, the uppermost, consists of a rich, gray limestone from one to two feet in thickness, abounding in fossils. The limestone is relatively soft, glistens with cleavage faces of calcite and is thin bedded and more or less shattered. In the eastern portion of the quarry the top ledge of this bed has an elevation of about 660 feet above sea level. The second, or bed B, has a thickness of 4 to 4½ feet and in places is nearly or quite without a seam. In other portions of the quarry it is divided into thick beds. The rock is a compact, brownish limestone which assumes a bluish gray color on weathered surfaces. Fossils large enough to be seen with the naked eye are not as abundant as in the overlying bed and the cleavage faces are smaller. The rock gives a strong bituminous odor and drops of oil are occasionally seen in fresh specimens. With dilute hydrochloric acid a brisk effervescence is always obtained when the cold acid is applied to the solid rock. Toward the bottom the bed becomes somewhat cherty and in places there is interposed between this bed and the underlying bed C a seam of impure chert, varying in thickness from one to two inches. At the same horizon there is also to be seen in places a one inch seam of blue clay, more or less charged with sand. The main excavation of the quarry has taken place in these two beds but two deeper ones have been penetrated and their characteristics determined. Bed C has a thickness of seven to eight feet, is a soft limestone of a dark gray color, either without seam or very heavily bedded. Beneath this lies a somewhat similar eight foot bed, which the analysis shows is richer in calcium carbonate. The following table shows the chemical composition of these four beds, as determined by Mr. G. A. Kirschmeier, of Toledo.

	Bed A.	Bed B.	Bed C.	Bed D.
Calcium carbonate	90.80%	86.80%	77.60%	95.00%
Magnesium carbonate	6.87	11.60	17.41	3.86
Silica	.48	1.10	2.78	.81
Iron	.16	.12	.56	.41
Organic matter	1.69	....	1.63	....
Difference	.00	.38	.02	—.08
	100.00%	100.00%	100.00%	100.00%

Mr. K. J. Sundstrom, of Trenton, General Manager of the Sibley quarry and chemist for Church and Company, has analyzed specimens of the two upper beds with the following results:

	Bed. A.	Bed B.
Calcium carbonate	98.10 %	86.96 %
Magnesium carbonate	.63	10.08
Silica	.70	1.86
Iron oxide and alumina	....	.62
Sulphur	.055	.123
Difference	.515	.357
	100.000%	100.000%

From a careful study of the beds of the Sibley quarry it has seemed reasonably certain that the Macon beds are the equivalent of the deeper and better beds of that quarry. The analysis of the cores from the two test holes in the Sibley shows that their wonderful "9 foot bed" is from forty to fifty feet above the base of the series. The record of the Nogard well (Ch. III, § 8) shows at a depth of fifty-nine feet, a change from gray to buff limestone which probably marks the change from limestone to dolomite. If this is the correct interpretation, and there is much confirmatory evidence, bed D of the Macon quarry extends from thirty-eight to forty-six feet above the base of the Dundee formation. The actual difference in elevation between the top ledges of bed D and the "9 foot bed" is eighteen feet, this representing the amount of drop towards Trenton in the direction of the strike.

§ 2. Dundee quarry.

This consists of a rectangular excavation about 240 by 90 feet, upon the north bank of the Raisin, just back of the National Hotel in the village of Dundee. It is but a few feet from the water's edge, and as it is worked only in the late fall, was full of water at the time of each of several visits. Most of the information concerning the beds was obtained from Mr. Horace Pulver, the present owner, supplemented with a study of the blocks of stone piled about the quarry. The uppermost, or layer A, is two and one-half feet thick and consists of a rich, gray limestone, impregnated with oil and full of fossils. Fresh specimens are somewhat darker in color than those from bed A on the Macon, which it otherwise much resembles. Bed B is four and one-half feet thick and consists of a grayish brown limestone which gives a bluish effect on weathering. It shows but few fossils and is apparently identical with bed B on the Macon. The upper fifteen inches is said to be irregularly clouded and "gnarled." A third bed has been penetrated and found to be six and one-half feet thick. It is dark brown and bituminous and in the lower twelve to fifteen inches becomes cherty. Beneath this occurs a discontinuous seam of chert, carrying silicified fossils. It is of a light gray color, with brown streaks and is impregnated with black oil. It is very probable that this chert marks the same horizon as the similar seam in the Macon quarry and hence that bed B there is the equivalent of bed C in this quarry. Beneath the chert there occurs a heavily bedded five foot bluish layer, bed D, which becomes lighter colored towards its base. All the limestone in the quarry responds promptly to cold dilute acid upon the solid rock.

§ 3. Petersburg excavations.

No real quarry has been opened up in this vicinity so as to give a satisfactory rock exposure, but stone has been removed from the bank of the Raisin in ditching and also from the river bed. Mr. Jacob McCarthy, from a thirty year acquaintance with this region, was able to furnish the most complete information. In front of Spalding's flour mill, upon the river bank, just below the railroad bridge, a ledge of pure gray limestone was struck at a depth of about eight feet. A slab of this stone is now used as a horse block in front of the M. E. parsonage of the village. It is very probable that this is simply a drift mass of Dundee, similar to that described in § 3, Ch. II, as occurring upon the Stewart farm northwest of Monroe. In the river flats S. E. ¼, N. W. ¼, Sec. 4, Summerfield, farm of John Peters, ledges of limerock are said to be struck at a depth of five to six feet and it was intended to open a quarry here at one time. Upon land here, now owned by Louis Carman, a large block of Dundee limestone, eighteen to twenty inches thick, was removed while deepening a ditch. This block now lies in the barnyard of Mr. Carman's residence at the N. W. ¼, N. W. ¼, Sec. 31, T. 7 S., R. 6 E. where it is to be broken up and used as foundation stone. At the mouth of this ditch rock is struck with a probe at the depth of fifteen to twenty-four inches. Fragments have been removed here and the chips left scattered about indicate that it is a brown dolomite. According to Mr. McCarthy considerable stone has been removed from the river bed at this point and used for foundation walls in the village. Immediately below the dam the fall of water has cleared out a hole, laying bare the rock at a depth of fourteen feet below low water mark. This rock, Mr. McCarthy says, is blue-streaked limestone similar to that found in the Lulu quarry. So far as may be judged from the indications the break from the Dundee limestone to the Monroe dolomite is situated very near the village of Petersburg.

B. Monroe Beds.

(a) Quarries Above the Sylvania Sandstone.

§ 4. Woolmith quarries.

These are located in Exeter township, about half way between Maybee and Scofield, N. E. ¼, S. E. ¼, Sec. 29. The chief one is owned by the Michigan Stone and Supply Company, headquarters in Detroit, Truman H. Newberry treasurer. During the past season it has been operated by George E. Currie, a contractor of Detroit. A short branch of the Detroit and Lima Northern enters the quarry ground and furnishes the necessary shipping facilities. A quadrilateral opening has been made, about 500 by 300 feet and to a depth of forty-five feet. A small amount of water trickles into the quarry, which collects at the southwest corner, from which it is pumped to the surface. One of the largest crushers in the state is operated in connection with the quarry, along with six gangs and one double gang of saws. The stripping consists of two to eight feet of blue boulder clay. This increases in thickness rapidly towards the east, south and west; but less rapidly to the north. Eastward just across the road, its thickness is fifteen feet; two hundred yards south it is twelve feet; while southwestward towards Maybee it is eighteen to twenty. Nine different beds, more or less distinct from one another, can be recognized and may be conveniently numbered in descending order, as was done in the previous descriptions. The direction of their dip is approximately W. 25° S. and the amount is two to three degrees. This is entirely local, the beds here being pushed upward into a knoll similar to that seen in the Sibley quarry. Bed A is a light colored, finely laminated dolomite, responding but slowly to cold dilute acid unless the rock is powdered. It is mainly of creamy white, but is blotched and streaked with dark gray to brown. Its thickness varies from two to four feet, being thinner in the eastern part of the quarry where in places it has been entirely removed by the great ice sheet, permitting the next lower bed to become glaciated. Its upper surface is smoothed, polished and striated. Where most weathered the rock becomes somewhat soft, mealy and gritty to the feel. In places it is porous and cavernous owing to the dissolving action of the surface water and sink-holes "large enough to take in a horse" were discovered when the stripping was first removed. When weathered the *Stromatopora*-like lamination becomes more apparent, and is similar to that observed in the Gibraltar and Grosse Isle quarries and in the upper part of the bed there occurs a similar stratum of gasteropod moulds and casts. Where nearest the surface the individual layers are thin, but become thicker toward the western part of the quarry where the rock assumes a bluish cast. Bed B is the three and one-half to four foot bed of dolomitic oölite previously described in § 7, Ch. III. Its lower surface is rendered very irregular by the hummocky nature of the upper surface of bed C. In conforming to these large hummocks the bed becomes laminated, a character which it does not elsewhere exhibit. Small cavities carry celestite, calcite and a little native sulphur. Bed C may be traced entirely around the walls of the quarry, varying from fourteen or fifteen inches to three feet in thickness. It is a drab to brown dolomite, in places almost as homogeneous, tough and campact as "lithographic stone," but in others it is open and cavernous the stone appearing soft and rotten. The large hummocks above referred to may be several feet in diameter, and the rock composing them consists of fine concentric laminae, convex upward. Large cavities contain celestite, calcite and sulphur and above and below the bed there occurs a thin seam of impure asphaltum. The underlying bed D is a dark brown to gray dolomite varying towards blue. It attains a thickness of five feet but may be reduced to one foot where the bed D is correspondingly increased. Its component layers are from two to eight inches thick and are, in places, plainly laminated with streaks of blue, gray or brown dolomite and delicate films of carbonaceous material. This character is more pronounced and the heaviest bedding occurs in the deepest, southwest corner of the quarry. Compared with the beds C and E this one is much more compact and free from the mineral bearing cavities, but it is more or less impregnated with oil. Locally it contains multitudes of a minute *Leperditia* and a miniature *Spirorbis*. Beneath this compact layer lies a much more open and cavernous one, bed E, from one to three feet thick, known locally as the "sulphur bed." It is a dark brown porous dolomite thoroughly impregnated with oil, giving it a strong bituminous odor and filling it with black blotches. Casts and moulds of simple corals, brachiopods and lamellibranchs are much more abundant than in the adjoining beds. Numerous cavities, more or less ellipsoidal in shape and in varying size from a fraction of an inch to two or three feet, are found throughout the bed. These cavities contain beautiful crystallizations of calcite, celestite and sulphur, intermingled in such a way as to indicate that they were simultaneously deposited from percolating water.* Upon a level with this bed there escapes into the quarry a stream of water from which sulphur is still being deposited; white, soft, and mealy looking at first but becoming

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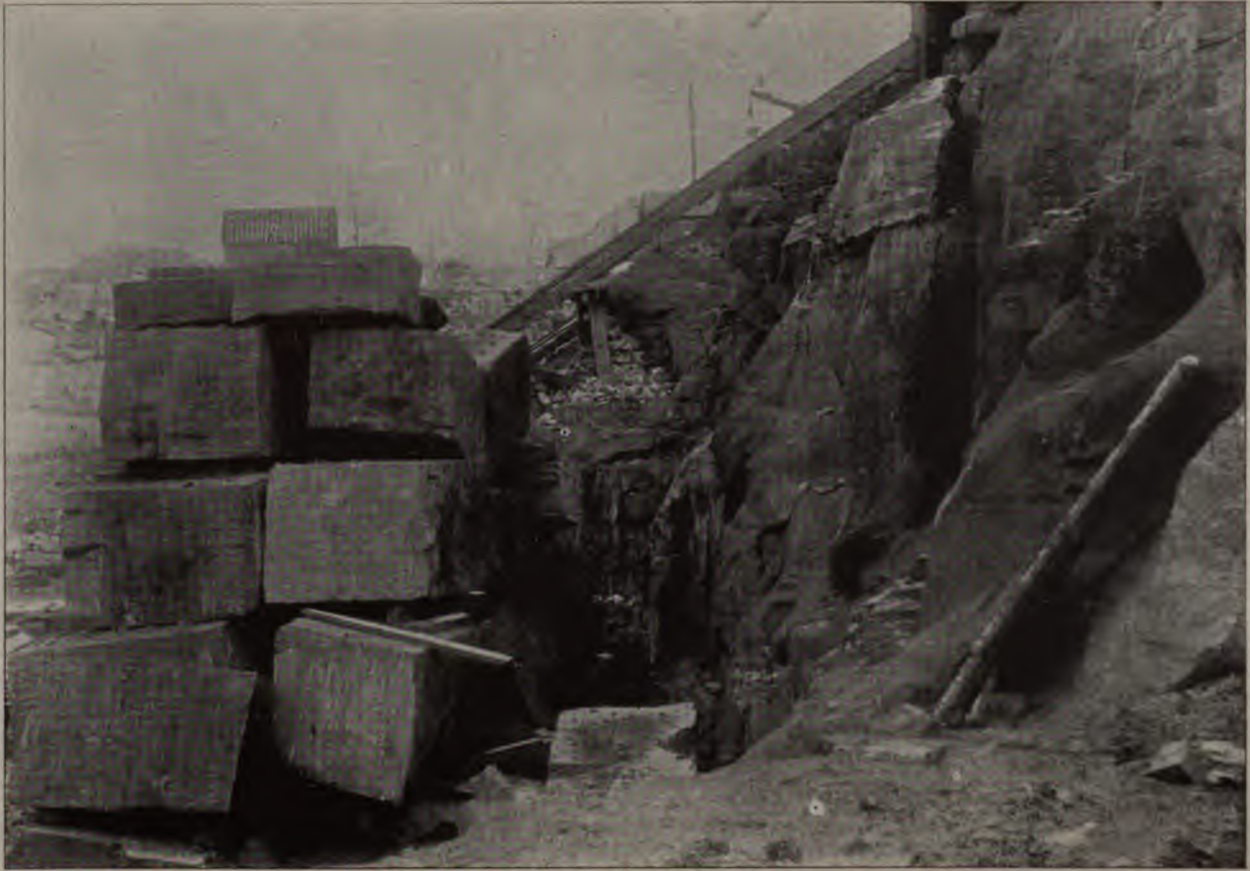
*Sherzer, Am. J. Sci., Vol. L, 1895, p. 246.



WOOLMITH QUARRY, SOUTH WALL, SHOWING MASSIVE BLOCKS OF SILICIOUS DOLOMITE.

yellowish upon exposure. Portions of the bed are compact and furnish building stone of a brown, bituminous character.

The five beds above described are essentially dolomitic limestones and sharply separated from the underlying beds F. G. and H, which consist of a mass of sand grains embedded in a dolomitic matrix. The uppermost, or bed F, varies in thickness from two to three feet and from its blue color it is one of the most conspicuous in the quarry. It has a gritty feel and becomes almost a sandstone in certain layers. It is permeated with vertical flexures, sub-cylindrical channels about three millimeters in diameter and several centimeters in length. These contain carbonaceous matter and oil and probably mark the position of seaweeds about which the sand and dolomitic slime accumulated. The channels are more abundant in the upper part of the bed and occur sparingly in the lower part. Near the top it becomes laminated with black, bituminous streaks. Towards the bottom the bed loses its blue color, becomes blotched with brown and merges into bed G. These blotches and streaks of chocolate brown fade out and we have a gray, highly silicious dolomite, from three to four feet thick. This passes without break into a beautiful sixteen foot bed (H) of light gray silicious dolomite, which is marketed as a "sandstone." This is so solid and free from seam that immense blocks may be cut out by means of steam chisels as shown in Plate II. When broken the rock gives a very coarse, conchoidal fracture. Occasional "glass seams" and dark streaks of grains of iron oxide somewhat disfigure the rock for building purposes. The dilute acid gives but slight action upon the solid rock, but upon the powder the acid gives brisk effervescence. Five grams of this powder give 1.37 grams of insoluble residue, or 27.4%, consisting of some alumina, with bituminous matter, but mostly of a white sand resembling that of the Sylvania bed. Examined under the microscope these grains are found to have been secondarily enlarged against the rhombohedrons of dolomite, giving them a roughened exterior and proving that the enlargement took place after the formation of the bed (see § 6, Ch. III). This series of silicious dolomites has a thickness of 21 to 23 feet in this quarry. Beneath lies bed I, a compact, even grained, gray dolomite heavily bedded. This has been penetrated fifteen feet and found to rest upon the Sylvania sandstone. Analyses of samples from the Woolmith quarry were made in 1895 by Prof. McDermott with the following results:

	4 feet down.	18 feet down.	24 feet down.
Silica	6.19	3.06	97.76
Iron oxide and alumina	.45	.31	.55
Magnesium carbonate	43.53	44.59	1.43
Calcium carbonate	50.12	52.72	1.14
Difference	—.29	—.67	—.88
	100.00	100.00	100.00

The first sample may have been derived from either bed A or B, depending upon the part of the quarry from which it was taken. The second very probably came from the bed E, while the third, representing a typical sandstone, must have been a poorly selected sample from beds F or G. The three upper beds of the Woolmith quarry are also seen in the small opening upon the adjoining property, to the south, belonging to John Hoffman. From four to six feet of clay stripping cover the rock, which has been entered ten to twelve feet.

§ 5. Raisinville quarries.

A series of six quarries occurs near the river in Raisinville township, which owing to their location and the similarity in their strata may be conveniently grouped together for description. The largest and most important of the six is owned by Robinson and Taylor, of Detroit, and is operated by Silas A. Kring for lime. It is located upon claim 516 (North River Raisin), at Grape and consists of two main excavations, one upon either side of the highway. From twelve to fifteen feet of strata are exposed, corresponding to the lower part of bed H and to bed I of the Woolmith quarry above described. The stripping is reduced in places to but a few inches of clay, charged with irregular fragments of the shattered dolomitic beds. The rock is estimated to dip 2° to 3° toward a little south of west. Upon the north side of the road the silicious dolomite forms the uppermost ledge on the west quarry wall. It is of a buffish gray color, gritty from the numerous sand grains, with numerous small irregular cavities, many of which are filled with calcite and give a spotted effect to the rock. The main quarry rock consists of a buffish gray, compact dolomite, faintly glistening with minute cleavage faces. It is thin bedded and much fissured towards the top but more heavily bedded, and more silicious toward the bottom. Nodules of impure chert occur and lenticular masses several feet long and five to six inches thick through the center. The following analysis was reported to have been made by J. D. Pennock, chemist for the Solvay Company, Detroit:

Magnesium carbonate	45.01
Calcium carbonate	51.69
Silica	3.45
Iron oxide and alumina	.20
Calcium sulphate	.43
Difference	—.78
	100.00

Just west of the quarry, upon land belonging to John Knaggs, (claim 428, North River Raisin) there is an outcrop of the same strata upon the south side of the road. A quarry was opened at this place and rock removed to a depth of twelve feet for building purposes. Not having been operated for some time the small excavation is now filled with debris and there are exposed only the protruding upper layers. Over a considerable area about this outcrop rock can be struck with a three foot probe. A quarry similar to that of Robinson and Taylor might be here developed. Beneath each the Sylvania sandstone must be expected to be reached very soon, so that neither could be extended to any depth with a yield of dolomite. The main stratum of dolomite in these two quarries, bed I of the Woolmith quarry and the bed found to overlie the Sylvania at the Toll pits, are apparently identical.

Directly south of these two quarries, upon the opposite side of the river, Fritz Rath has opened up two small quarries upon claim 685. The most northern is located some 250 paces northeast of the residence and consists of a rectangular opening, 70 by 85 feet. This was worked for lime about twenty years ago, the quality of which was reported to be good. At the time of the visit the quarry was filled with water but numerous fragments of the rock were found scattered about. These indicate that the beds are a dark brownish dolomite, streaked and finely specked with a creamy white, looking very much like a very obscure oölitic structure. Upon dissolving a flake of the rock in acid there is left behind a quantity of pure white rounded sand grains, varying considerably in size. These are secondarily enlarged against the rhombohedrons of dolomite, and oölitic granules, as in the case of the Woolmith rock previously described, giving their surfaces a very rough appearance under the low power of the microscope. The clay covering here is said to be eight to twelve feet thick. South of the Rath residence about one quarter of a mile a natural exposure occurs, at which three small linear excavations have been made for rock for building purposes, exposing five to six feet of the series. The upper bed is four feet thick and is a light to dark brown dolomitic oölite in which the structure is much obliterated. Upon dissolving small fragments in acid a considerable quantity of fine snow-white sand grains remain. These resemble those previously described, being secondarily enlarged and roughened. Occasionally one is seen with crystal facets developed or with the pyramidal termination. The rock appears to be a dolomite, enclosing sand grains and quantities of the varied oölitic structures previously described. It is associated with a gray, compact dolomite which resembles the main quarry rock upon the opposite side of the river, but shows some thin, narrow plant stems or leaves. Unless there is some local faulting here which would bring the Woolmith oölite down about thirty feet, it seems most probable that this represents a local modification of the lower layers of bed H of the latter quarry. In thickness and general appearance it resembles the Woolmith stratum but the latter upon being dissolved yields much more bituminous matter. In the well of John Nicols a core was taken out at the N. E. ¼, N. W. ¼, Sec. 26, T. 6 S., R. 7 E., to a depth of sixty-three feet. After passing through some hard pan this same silicious oölite was struck at nine feet, of which a three and a half inch core was secured. At a depth of about twenty feet a bed of white sandrock was reached which Mr. Nicols believed to have been seven to eight feet thick. Dolomite was then entered, which so far as may be judged from a single sample saved, was highly silicious.

Upon the lower portion of this same claim 685, Frederick Milhahn has opened a small quarry where the rock lies but one foot from the surface. Just across the fence to the west a second small opening has been made upon the land of Mrs. Nora Sullivan, claim 683. These lie about one and one-quarter miles southwest of the Grape quarries and have been operated ten years, mostly during the winter months, for building stone. The rock has been entered but three to four feet and is seen to be a heavily bedded, brown to gray silicious dolomite, having a rough gritty feel.

§ 6. Ida quarries.

One and one-half miles west of the village of Ida the rock strata again appear at the surface owing to local flexures. Just where the north and south quarter section line of Sec. 4 intersects the Adrian branch of the Lake Shore R. R., three quarries have been opened. The principal one has been operated for lime and building stone for many years by Nelson Davis. This is located to the south of the railroad in a field of about eight acres, one mile east of the Ann Arbor R. R. Superficial excavations have been made over a considerable portion of the field. The beds have no perceptible dip within the limits of the quarry and are drained by a small stream flowing southeastward. Mr. Davis recognizes two separate beds which he terms the first and second formations respectively. The uppermost attains a maximum thickness of seven to eight feet in the central portion of the quarry. Based upon excavations about the quarry, Mr. Davis believes that this bed gives out in each direction, from ten to fifteen rods north and east, about one-half mile west, and before it reaches Lulu, two and one-half miles to the southwest. It consists of a light gray dolomite which in places assumes a creamy white, owing to its partial or complete conversion into strontium carbonate *(strontianite)*. Near the middle of the quarry nearly a foot of the dolomite has been so altered, giving a soft, mealy rock with seams and films of the pure mineral. Some slabs are covered with a layer of slender well formed, orthorhombic prisms of this strontianite. The bedding is thin, varying from an inch, or less, to six or seven inches. Near the surface of the bed certain slabs show a remarkable amount of what may best be described as *gashing*. The rock looks as though, when it was only very slightly plastic, it had been jabbed in every direction with a thin bladed, double edged knife point. The gashes are almost always open, intersect one another irregularly and vary greatly in size, some being two-thirds of an inch long, while others can scarcely be seen without the magnifier. The cross section of each gash shows that it is thickest at the center and that it slopes gradually and symmetrically to a very thin edge. Traces of this peculiar structure are found throughout the Monroe series, from the highest rock seen at Petersburg to the lowest outcropping at Stony Point. It is not known what mineral could have crystallized in the dolomitic matrix and left these openings by its removal. One specimen from the Raisin bed shows them filled with calcite, but this may represent a secondary deposition.* In his report of 1860, Winchell refers to this as an *acicular* structure and infers that it is characteristic of gypsum. Rominger uses the term acicular also in describing the Ida rocks and calls attention to the widespread character of the phenomenon, but does not name the substance by which it may have been produced. It is to be noted that the crystals, however, were not needle shaped and only the cavities in cross-section give this appearance. In weathered specimens there are shown plainly the frondescent structures associated with the spherical granules in the beds of oölite previously described. These make up the body of the rock in places, their dim outlines showing in the solid dolomite. The oölitic granules are much obscured but are recognizable, proving that this bed is, in part at least, an oölite. In position it is the equivalent of the bed struck in the Nicol's well, above mentioned, and in the Rath quarry. The characteristic chocolate brown blotches are locally abundant. No fossils were collected from any of the strata. Rominger determined the amount of calcium carbonate in a sample to be 59% and of magnesium carbonate 39%.

Underlying this bed is the so called "second formation," which is well exposed in some of the deeper excavations of the quarry. This is a firm dolomite, dark when damp, but drying to a light gray. The surface of the bed is rough and irregular and the upper three to four inches porous and open, containing numerous moulds and casts of gasteropods, brachiopods and corals. Distinct lamination is to be seen in places. A drill core of this and the deeper beds was taken out in 1895; but the cores had been disturbed and some lost, so that the record obtained from them was unsatisfactory, except in a few cases where the depth had been penciled upon the core at the time of its removal. A silicious dolomite, streaked with blue, was found to overlie the bed of white sandrock struck in the Nicol's well. This latter appears to be six to seven feet thick, but contains much dolomitic matrix, and extends from about twenty-four to thirty feet of depth in the well. Beneath this bed lies a compact silicious dolomite, streaked and blotched with blue, which in turn, cannot be many feet above the surface of the Sylvania sandstone.

Just west of the Davis quarry there are two small excavations which have entered the "first formation" to a depth of two to three feet. The larger lies just west of the highway and north of the railroad upon the property of Michael Voight and the other to the south, upon the opposite side of the railroad, and belongs to Byron Wilcox.

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*I am inclined to refer it to calcite. It seems to be a widespread phenomenon at about this point in the geological scale, as I have noticed it frequently in the Upper Peninsula. See also Rominger Geol. Sur. Mich., Vol. I, Part III, p. 27, and Dana's Geology, p. 247 of the first edition. L.

§ 7. Lulu quarry.

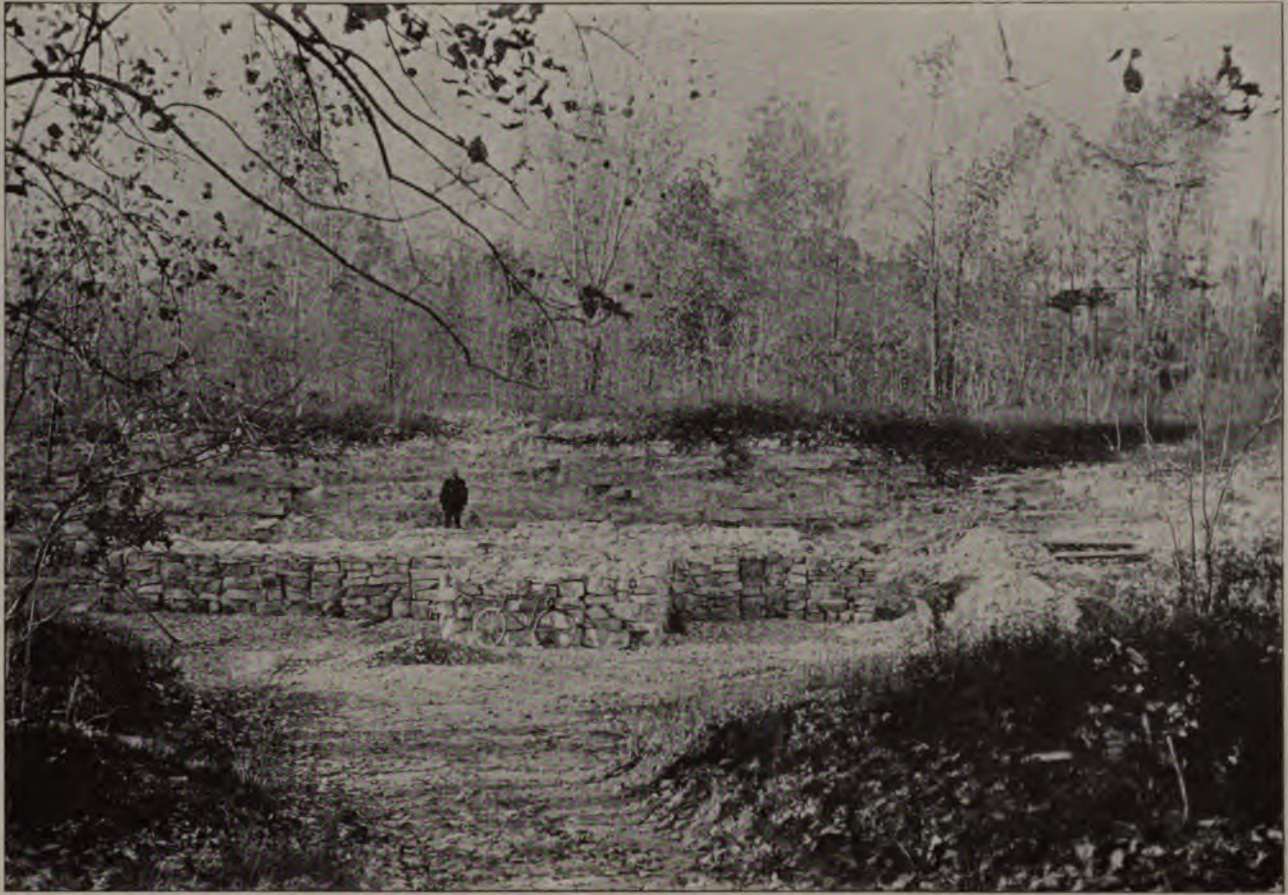
In Sec. 16, N. W. ¼, N. W. ¼, the rock rises to within three to five feet of the surface, upon land now belonging to Henry McCarthy. Rock for local building purposes was removed here fifty years ago and the main part of the quarry for many years was in possession of Henry Y. West, now of Lulu. The excavation contained too much water at the time visited to allow a satisfactory inspection of the beds, but they were seen to correspond with those penetrated by the drill in the Ida quarry. The strata have here been thrown into a fold giving a high local dip to the east and west by south. This might be a good place to test for oil. A v-shaped break extends northeast and southwest across the quarry on either side of which the strata are said to overlap "like shingles on a roof." The quarry has followed this break for nearly one hundred yards and the layers have been removed for a short distance on either side, the west wall furnishing the best exposure. An upper layer nine to ten inches thick, is a buff dolomite, highly charged with rounded sand grains, varying considerably in size. Beneath is a twelve inch layer of a less gritty, tough, light gray dolomite, succeeded by a white sandstone layer of the same thickness. These three feet represent the lower portion of the sandrock of which cores were obtained in the Davis and Nicol's wells. The main quarry rock consists of those dolomites which lie between this bed and the Sylvania proper, of which eight to nine feet have been exposed. These are compact gray dolomites, more or less mottled, streaked and blotched with rather vivid blue coloring matter. Some of the rocks much resemble in appearance, as Rominger suggests, castile soap. According to Mr. West there are two acres here over which rock could be easily quarried, lying within one quarter of a mile of the Ann Arbor R. R. An analysis of the dolomite gave Rominger the following:

Calcium carbonate	54%
Magnesium carbonate	42
Quartz sand	4

§ 8. Little Sink quarry.

A small but interesting quarry has been opened upon the eastern edge of what is known as the "Little Sink," to be later described. The excavation lies in the S. E. ¼ S. E. ¼ Sec. 2, Whiteford township upon land owned by Morris Cummins. Over an area of ten to fifteen acres the rock lies very near the surface, so that the scanty soil is practically unfit for agricultural purposes. The rock in some places is entirely bare of soil, while in others its thickness varies from one to two feet. Upon the west side of the quarry there is practically no stripping, but this reaches a thickness of one to one and one-half feet upon the eastern side. In passing southwestward from Lulu the surface of the rock is depressed, covered with a heavy belt of sand, and next reappears here at the surface in consequence of having attained an elevation above sea level of about 670 feet. The quarry is nearly equi-distant from the Ann Arbor R. R. and the Toledo-Adrian branch of the Lake Shore railroads, being about five miles from each in a direct line. In consequence, the markets are entirely local the demand being simply for building stone. The present quarry was opened about thirty-five years ago, but previously stone had been superficially quarried for building purposes and for the manufacture of lime upon a small scale. The opening is in the form of an irregular quadrilateral about 100 by 50 feet, and the strata have been penetrated from nine to ten feet. The water enters the crevices of the rocks through which it drains away except in the early spring, when the entire region is liable to be flooded.

Two fairly distinct beds may be recognized which overlie a pure white sandrock in which the grains are cemented by a dolomitic matrix. A comparison of these beds with those previously described shows that they are intermediate between the beds exposed in the Ida and Lulu quarries, being, indeed, those penetrated by the drill in the Davis quarry before the white sandrock was reached. The Lulu strata will then be exposed here by going deeper. The uppermost bed is thin-bedded and varies in thickness, within the limits of the quarry, from three to five and one-half feet. Typically it is a compact, tough, gray dolomite, showing a rather bright greenish stain in places. Towards the surface it is fissured and weathered considerably, showing a rusty iron coloration. The rock is penetrated with numerous channels which seem to be the preserved bur-



"LITTLE SINK." CUMMINS QUARRY. SHOWS ALSO SCANTY SOIL AND STUNTED FOREST GROWTH.

rows of marine annelids. Fossils are abundant at certain levels. The second bed is three and one-half feet thick and is a gray dolomite streaked horizontally with blue, as seen in the Lulu quarry. In the upper foot of this bed these blue streaks are altered to a rusty brown, suggesting that the blue coloration is due to some oxidizable compound of iron. No fossils were observed in this bed except a faint trace of a cephalopod. A few cavities occur in which are found crystallized masses of calcite and strontianite. There also occur some peculiar stylolites, in the form of sub-cylindrical plugs, in diameter ranging from one and one-half to eight inches and in length from one and one-half to seven inches. They are set vertically in the strata with their upper ends on a level with the surface of the rock. They separate quite readily from the rock in which they are embedded and show the peculiar splintery surface, which characterizes these structures. Occasionally one is seen which is well defined above but which gradually merges into the rock of the stratum and its form disappears. The film of carbonaceous matter commonly present is here represented by an iron stain, or by the blue coloring matter with which the bed is streaked. These plugs have the same composition as the surrounding rock and on being broken show no internal structure. The upper end of each is deeply concave and in every one observed there is a small handful of angular chips of dolomite loosely cemented together. The most plausible explanation seems to be that in the general disturbance of the region the rubbing of the strata over one another detached the small chips. Some of these collected in the cavities at the upper ends of the stylolitic plugs and were preserved, while those which remained between the strata were ground to powder. The structures themselves strongly suggest an organic origin but are believed to have been caused, in some unknown way, by pressure. A small sink and quarry occur upon the place of Daniel Rabideu at the S. W. ¼, N. W. ¼, Sec. 10. This lies about half way between the quarry just described and those to be described in the next paragraph. Only a small amount of stone has been removed. It is a horizontally streaked dolomite, of a dark drab color, containing some minute calcite crystallizations.

§ 9. Ottawa Lake quarries.

These are located near the head of the lake in the east central part of Sec. 7 and the west central part of Sec. 8, Whiteford township. They represent one nearly continuous irregular excavation but lie upon the adjoining properties of no less than seven different individuals. The main excavations belong to Ezra Daniels and Frank Kane and are in the S. E. ¼, N. E. ¼, Sec. 7. The rock in this region attains the highest elevation of any in the county, being about 680 feet above tide, or 107 feet above the level of Lake Erie. The dip of the beds is irregular, but high compared with that in other quarries of the county. In the Daniel's quarry it ranges from four to nine degrees and in direction is approximately W. 20° S. Owing to the elevation and channeled condition of the strata there seems to be no trouble with quarry water. Ottawa Lake station is distant two and one-half miles but the railroad itself is less than two miles from the quarry in a direct line.

Four beds may be recognized which may be conveniently referred to by letters as in preceding descriptions. The uppermost, or bed A, is a compact, gritty dolomite of a buffish brown color. Dilute acid applied directly to the cold solid rock gives but little action, but when the rock is powdered and the acid heated the action is vigorous and continues for a considerable time. There is finally left a little brownish sediment and a considerable quantity of fine sand grains, which give the same appearance under the microscope as those found in the Woolmith silicious dolomites. The surface of the bed is more or less broken and softened by water action, the dolomitic matrix being partially dissolved, leaving behind a rock relatively richer in sand. The entire stratum thickens in the direction of the dip, becoming thinner and thinner bedded toward the north and east. Bed B is a cherty layer having a thickness of twelve to eighteen inches in the Daniels quarry, but thinning rapidly northward and disappearing upon the west wall of the Kane quarry. The chert is much shattered as by earth movements and is impure, being altered in places to a soft, gray, mealy substance. Considerable clay has been deposited in the crevices, undoubtedly from surface water. The bed yields some fossils. The main quarry rock is obtained from bed C which is a compact dolomite of the same general character as that of bed A. The lower layers have a deep blue color, which in the upper part of the bed has all been altered to a buff. The same change in color has occurred lower down along seams and near the surfaces of the individual strata, so that much of the rock quarried from this bed shows only a blue core. Numerous ellipsoidal concretions occur, reaching a diameter of five to six inches, and one stylolitic plug was found, similar to those seen in the Little Sink quarry. This bed attains a thickness of nine to ten feet with two quite distinct structural breaks. Bed D forms the floor of the Daniels quarry and shows two feet in the McQuarrie quarry to the northeast, where it was burned for lime but found to yield a poor quality. It is a buff to gray compact dolomite, gritty to the feel and showing some carbonaceous films. In the latter quarry the strata are nearly horizontal, but in the Daniels quarry drop off rapidly in the direction of the dip from an open seam which extended in a northeast and southwest direction. In the quarries immediately adjoining those above mentioned the same silicious dolomite is exposed. About two hundred paces eastward a small opening was made and rock was quarried for lime to a depth of three to four feet.

At the northern end of the lake, upon a level with the water when it is full, there occurs an outcrop of a gray dolomite, S. E. ¼, S. E. ¼, Sec. 7. An old side hill lime kiln was operated here thirty-five years ago by Walter K. Hadley, now deceased. The rock was quarried only while the lake was dry. In general appearance and fossils it much resembles the upper bed in the Little Sink quarry. At the lower end of the lake a buffish brown compact dolomite outcrops in the bed of the small stream known as the Inlet, S. E. ¼, S. E. ¼, Sec. 19. On the north bank of this stream and just west of the railroad there stands the ruins of an old lime kiln, showing that rock was quarried from the Inlet and here burned. A small artificial opening, two to three feet deep, lies north of the stream and east of the highway and furnished rock also for the burning. This is a fine grained, drab dolomite smooth to the feel and much resembling bed I of the Woolmith quarry, with which it should be correlated. The silicious dolomites at the head of the lake are believed to be the equivalent of the overlying silicious beds of the Woolmith, differing chiefly in the character of the bedding.

The foregoing descriptions are believed to cover all the localities from which rock has been thus far quarried for any purpose from the Monroe series above the Sylvania. The dolomites seen at Flat Rock, Gibraltar and Grosse Isle belong to the same set, lying between the Sylvania sandstone and the Dundee formation exposed at Trenton. An analysis of material obtained by a drill from these beds in the N. E. ¼, S. W. ¼, Sec. 8, Ash township is kindly supplied by General Manager S. T. Crapo, of the Pere Marquette R. R.:

Calcium carbonate	55.03%
Magnesium carbonate	42.17
Iron oxide and alumina	.48
Silica and other insoluble residue	2.32
	100.00

(b) *Quarries Below the Sylvania Sandstone.*

§ 10. Newport quarries.

The fold in the dolomite layers which constitutes the "ridge" passing from Sylvania northeast to Stony Point, has brought the rock very near the surface in many places and a large number of small quarries have been opened upon it. Following the strike of the beds very closely, as does this fold, there is much sameness in the general appearance and composition of the rock exposed in the numerous openings. Towards the base of the Sylvania sandstone the dolomite becomes highly charged with rather coarse sand grains, as seen in the Smith quarry west of Newport, and in the rock removed from the bed of the Raisin. The deeper beds are more homogeneous and compact, of a light or dark drab color and are all true dolomites. Fossils, in the form of moulds or casts occur in many places and will be treated in the last chapter of this report. The bed of oölite which has been previously traced and described, happens to occupy the crest of the ridge for a long distance and is much in evidence for a bed of such thickness. The most northern openings in this series may be conveniently grouped as the Newport quarries. The most important of these lies in the N. E. ¼, S. E. ¼, Sec. 1, Berlin (T. 6 S., R. 9 E.) just south of the village of Newport Center, upon the west side of the Michigan Central R. R. The quarry consists of a roughly rectangular opening about 200 by 50 feet. At the time of visit it was filled with water, so that its depth and the beds represented could not be satisfactorily determined. The rock is of a dark drab color, certain layers being charged with fossils, but all the calcium carbonate has been dissolved. A small crusher was operated for a time in connection with the quarry, but work has ceased and the building and machinery have been removed. In the village of Newport Center, from the Lake Shore R. R. bridge, up Swan Creek for a distance of a quarter to a third of a mile, rock is readily reached in the stream and along the banks. Irregular openings have been made upon the places of Cartwright and Brancheau and rock removed for local building and construction work. Samples taken show that it is of the same character as that above noted. One and one-half miles west, upon the land of Mrs. Lizzie Smith, S. E. ¼, S. E. ¼, Sec. 34, of Ash township, a rectangular quarry has been opened having the approximate dimensions 100 by 80 feet. This also was full of water at the time of the visit. The hand samples taken show that the beds here are more or less silicious, of coarse, rounded sand grains embedded in a drab, dolomitic matrix. One specimen is a buffish gray grit, with dolomitic cement. These beds are the highest in the series of any exposed in the quarries that remain to be described and are from twenty to thirty feet below the base of the Sylvania sandstone.

§ 11. Frenchtown quarries.

In the southern part of this township the ridge changes its northeasterly course rather abruptly, swings around to the southeast and strikes the Lake at Stony Point and Point aux Peaux. In its course across the township it furnishes the sites for several quarries. The most northern of these is that upon claim 529 (south of Swan Creek), belonging to Henry G. Sissung. There are said to be here 160 acres of land over which the stripping will not average more than two feet. The quarry was opened at an outcrop some fifteen years ago where the stripping increases to the southwest. The rock dips southward a few degrees. The strata average eight inches in thickness and about seven feet have been penetrated in the deeper portions of the quarry. They furnish good building stone for the local market, consisting of compact gray and drab dolomite. A much larger opening lies upon the same claim to the southwest upon the place of Richard Labeau. Its dimensions at the time of visit were about 240 by 175 feet, superficially quarried. The character of the beds and of the rock resembles that of the Sissung quarry. In the bed and along the banks of Stony Creek, at Brest, a small amount of rock has been quarried for the local market. The exposures extend from the highway up stream for a third of a mile. The lower bed consists of a gray dolomite, filled with small, irregular cavities from which fossils have been removed by solution. Above this lies a bed of more compact darker dolomite, mottled with blue as in the case of the Lulu and other quarries located above the Sylvania sandstone. Still higher lies the bed of oölite previously described and best seen upon the property of Mrs. Mary Emerson. Following southwestward where Sandy Creek crosses the ridge, for a distance of three-fourths of a mile, rock can be struck with a probe and appears at frequent intervals in the bed of the stream. A small amount of the rock has been removed upon the place of Peter Suzore. It is a tough, compact rock of a grayish drab color.

The most important quarry in the eastern part of the county is the one now being operated by the Monroe Stone Company. This is located in the southern part of Frenchtown, about two miles north of the city of Monroe, claim 64, North River Raisin. It lies between the Lake Shore and Michigan Central tracks and is connected with the Pere Marquette by means of a switch, so that the shipping facilities are all that could be desired. The quarry was opened in September, 1895, since which time work has been actively pushed and an immense amount of rock crushed and marketed. The stripping averages about two and one-half feet varying but little toward the east and west. Two hundred feet to the south it equals four feet in thickness while one hundred feet north it equals three feet. The upper layer is glaciated above, as is uniformly the case in the county. For fourteen feet the rock is thin bedded, the strata varying in thickness from two inches at the top to ten inches below, and is shattered and broken so as to have no value for building purposes. It is a dark drab dolomite, of fine grain and even texture, breaking with rough conchoidal fracture and sharp edges. Thin, wavy carbonaceous films traverse the rock. Between the strata are layers of a soft putty-like clay which hardens upon exposure. These sometimes reach a thickness of two inches and represent surface material brought in by percolating waters. A good view of the bed as seen upon the west wall of the quarry is shown in Plate IV. At the base of these beds there is a thin stratum of *breccia* made up of angular fragments of a deep blue dolomite, another which is finely laminated and further, fragments of oölite, all contained in a drab, dolomitic matrix. Beneath this lies a bluish gray layer, streaked and mottled with a deeper blue coloring substance. Two large sink holes were encountered in the quarry, which at the time of examination was in the form of a semicircle, with a radius of about 130 feet. These holes were well like openings with a diameter of six to ten feet, containing at the bottom a mass of irregular fragments, cemented with crystallized calcium carbonate. The following analyses of the rock from the upper and main beds were kindly supplied by Mr. K. J. Sundstrom:

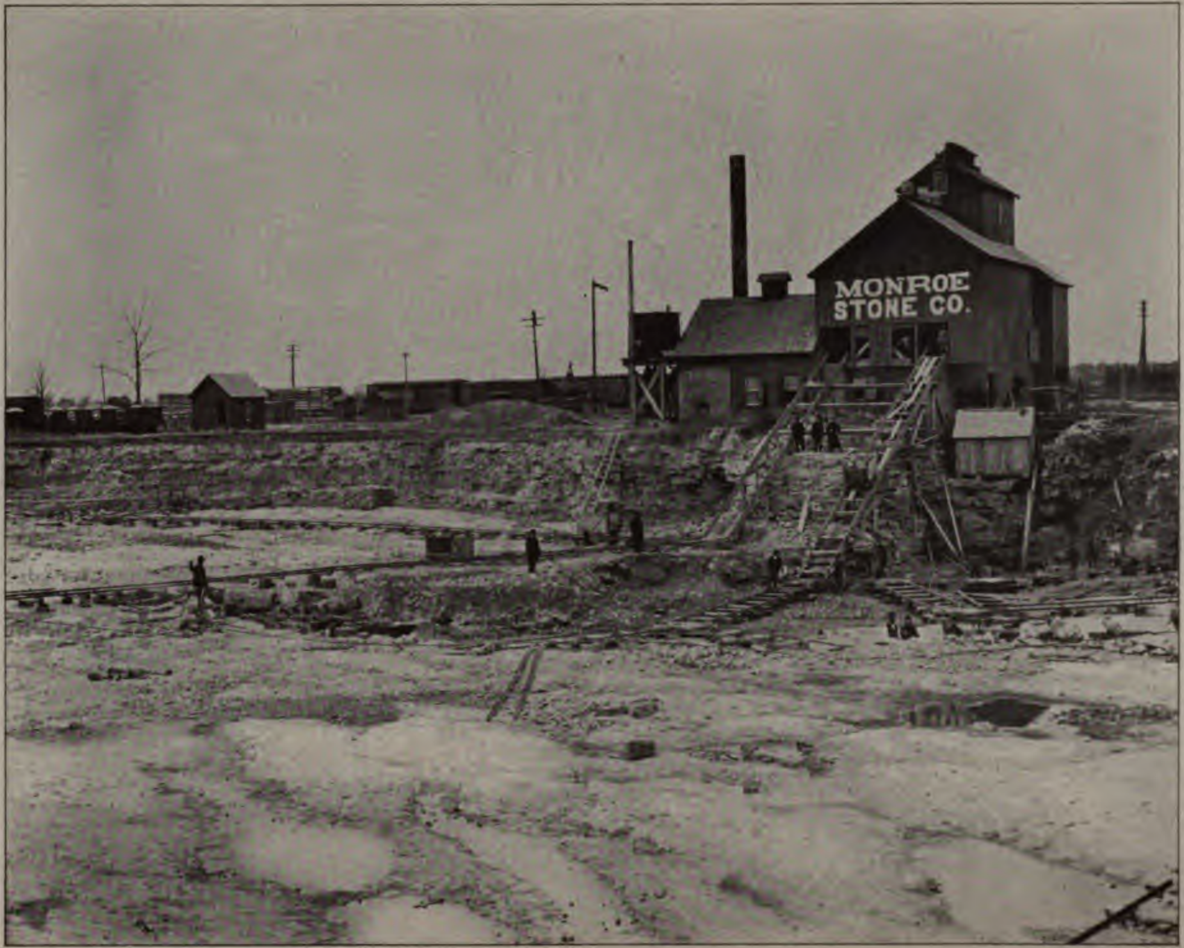
	2 feet down.	7 feet down.	10 feet down.
Calcium carbonate	54.54%	54.47%	54.94%
Magnesium carbonate	42.75	43.59	42.84
Silica	2.00	.74	1.33
Iron oxide and alumina	.70	.98	.58
Difference	.01	.22	.31
	100.00%	100.00%	100 00%

§ 12. Monroe quarries.

To the south of the city of Monroe there have been opened several quarries of more or less importance, chiefly in the immediate vicinity of Plum Creek. Some of these furnished building stone and lime in an early day to the French settlers of the region. The main excavations are upon the north side of the creek and lie upon adjoining divisions of claim 498, belonging to Alexander T. Navarre and Mrs. Mary T. Navarre. The stripping consists of a stony, yellowish brown clay, from three and one-half to five feet thick, deepening mainly towards the west. In the northeastern part of the irregular excavation two fairly well defined folds intersect one another, one bearing N. 45° E. and the other N. 60° W. From these ridges the rock dips in four directions from two to five degrees. In the A. T. Navarre quarry the dip is approximately one to two degrees toward N. 61° W. Here four beds may be recognized, the upper of which is termed the "white bed." This is a gray to creamy white dolomite, six to seven feet thick, thin bedded and fissured above, but thicker toward the base. Many loose pieces of this bed are in the clay stripping, softened upon the surface to a mealy powder. At the lower part this bed passes into a nine to ten inch stratum, which is very compact, even grained, somewhat laminated, and sparingly streaked with blue. The rock is brittle, gives sharp edges and coarse, conchoidal fracture. Owing to its higher specific gravity it is known in the quarry as the "lead bed." Beneath this lies a two foot "gray bed,"made up of a fossiliferous, light drab dolomite, carrying some films of carbonaceous material. The lowest bed exposed in the quarry at the time of the visit is the so called "blue bed." This is a compact heavily bedded dolomite, inclining to drab on fresh fracture but having a decided bluish surface upon standing. Struck with a hammer the slabs give out quite a ringing sound. The individual strata have very rough upper surfaces, covered with black carbonaceous deposit. The blue color is not so marked in the portion of the quarry belonging to Mrs. Navarre and the bed not so sharply separated from the overlying one. A local deposit of brecciated material similar to that found in the sink holes of the Monroe Stone Company quarry, was observed at one place. Upon the south side of the creek the rock lies very near the surface and a linear excavation extends for a considerable distance parallel with the stream. It is here that the bed of oölite, previously described, appears. Above it is a creamy dolomite, becoming somewhat blue, while beneath is a compact, laminated bed, streaked horizontally with a rusty brown. Judging from the alteration in the mottled dolomite seen in the Little Sink quarry this bed is of the blue streaked variety. These beds underlie those above described, as well as those in the quarries north of the city.

One-half mile down stream a large quarry has been opened between the two railroad tracks by the Michigan Stone and Supply Co., the owners of the Woolmith quarry. The excavation is in the form of an irregular rectangle about 450 by 125 feet. At the time of the visit it was well filled with clear blue water so that the strata could not be examined. Toward the north side the depth is said to be thirty-two feet, penetrating a lower series of beds than are seen elsewhere in the county. The rock was used entirely for road purposes and a crusher was operated in connection with the quarry. For five years no work has been done here, owing, it is reported, to the damage done to neighboring houses by the blasting. The ledges exposed above the water are thin-bedded fissured dolomites, of a light color. In the stone pile at the crusher there are seen fragments of a compact, fossiliferous, drab dolomite; another of a bluish color and conchoidal fracture and a third blue shaly rock, friable and carrying carbonaceous seams. The former foreman says that the strata are very much disturbed in this quarry and "run every way."

During periods of low water in the Raisin, rock is quarried directly from the bed opposite the city and for a distance of three to four miles above, at frequent intervals. The lower beds thus exposed consist of gray and drab dolomites, the latter finely laminated. A view of these layers is shown in Plate VIII, but was not taken at the lowest stage of the water. Opposite claims 65 and 88 (North River Raisin) the rock is a creamy yellow dolomite, in some



MONROE STONE COMPANY, CRUSHER AND WEST WALL OF QUARRY.

layers very finely laminated. Further up the river the higher beds occur and are seen to become more silicious as the Sylvania sandstone is approached. In Willow Run, at its mouth a thin layer of sandstone occurs, which much resembles the Sylvania except for the greater coarseness of its grains. Near the top of the series there occurs a stratum of bluish gray and brown chert, somewhat brecciated and carrying obscure fossil remains.

Within a distance of a half mile south of the Plum Creek quarries four small openings have been made and rock removed for local purposes. Some two hundred paces south a small field quarry has been opened upon claim 498, belonging to Alexander T. Navarre. From three to five feet of bluish to buff dolomite are exposed. Locally the strata are laminated, in places homogeneous. The rock weathers to a soft, mealy substance of a creamy color. Numerous fragments are loose in the clay stripping, which varies in thickness from a few inches to three feet. About one hundred paces to the southwest of this quarry Dennis Navarre has a small field quarry into the same bed. Some of the rock shows the brownish mottled effect seen on Plum Creek in the beds associated with the oölite. The two other quarries are upon the same claim and are upon the banks of Tamarack Creek. The most westerly one belongs also to Dennis Navarre and is located near his residence. The opening is three to four feet deep and was filled with water at the time of the visit. The bed of oölite is here exposed and some of the overlying dolomite, which is creamy and slightly mottled. For a distance of about 300 paces down stream the rock appears in outcrop and an irregular quarry has been opened upon the property of Patrick Navarre. The rock is thin-bedded and fissured above, but the deeper layers attain a thickness of nine to ten inches. The upper strata are buff to gray and mottled with brown to a depth of four feet. Beneath this the rock is compact and of a drab color. The strata here dip 7° toward N. 16° E., both of which are abnormal.

§ 13. La Salle quarries.

No quarries of any magnitude or especial importance have yet been opened south of Plum Creek, but the rock is near the surface in many localities and the railroads are near at hand to give the necessary shipping facilities. Excepting the bed of oölite previously noted, the rock is a gray to drab dolomite, generally compact and adapted for road metal, of which the region generally stands in great need. Within the limits of La Salle township a number of minor quarries have been started, of which but little more than mention may be here made. In the bed of Otter Creek, just west of the Pere Marquette bridge, rock is now being quarried and for a distance of a mile up stream rock is accessible. Upon claim 436 (South River Raisin) Charles Heck has removed a small amount of stone from the south bank of the creek. In Sec. 20 along the south branch of Otter Creek, the surface of the rock has been reached by the stream for a considerable distance. In the N. W. ¼, N. E. ¼ of this section a quarry was opened along this branch and considerable rock removed by Jacob Clock. In the northern part of Sec. 32 and southern part of Sec. 29, along Muddy Creek, the rock is so near the surface that it had to be blasted out in deepening the stream. Some rods south in the N. W. ¼, S. E. ¼, Sec. 32, an irregular quarry, with ruins of a lime-kiln, is situated upon the land of W. W. Green. Further south in the same section, S. W. ¼ S. E. ¼, Mr. Edward Green has a small opening south of his residence. A still smaller opening was made in the N. W. ¼, S. W. ¼, upon the place of Saml. B. Cousino. Eastward in the S. W. ¼, S. W. ¼, of Sec. 33, a considerably large opening has been made upon the ridge by Eli Cousino. The quarry is an irregular one 300 by 75 feet and eight to ten feet deep, with a small test hole a short distance to the southwest. These openings are very near the north and south section line, to the east of the residence. The rock is the common type of drab dolomite, in rather thin layers.

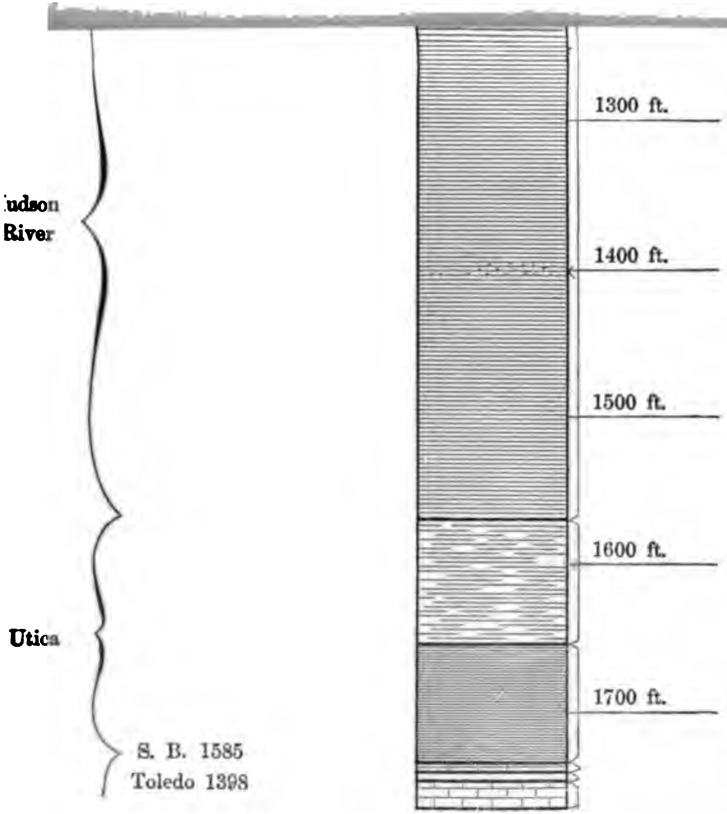
§ 14. Bedford quarries.

Three small quarries have been opened near together and excavated to a depth of two to three feet at the center of Sec. 12, Bedford township. The largest of the three belongs to M. Butler and is in the S. W. ¼, N. E. ¼. At the time of the visit it was filled with water as is usual in the case of quarries that stand idle for a length of time. The rock samples collected show that the rock is a somewhat incoherent and not homogeneous drab dolomite. In the N. E. ¼, N. E. ¼, of this same section Thomas Blouch has opened a quarry in Bay Creek ditch, which extends some 200 yards along the stream. The stripping varies in thickness from two to four feet and the rock is a compact, drab dolomite. On the opposite side of the road, upon the place of C. L. Osgood, S. E. ¼, S. E. ¼, Sec. 1, similar rock has also been quarried. About Little Lake in Sec. 15, the rock again approaches the surface and furnishes the sites for five small irregular quarries, exposing a few feet of the beds associated with the oölitic stratum. Three of these quarries are located on adjoining land at the center of the N. W. ¼ of Sec. 15, and belong to Misses J. and N. Ferguson, Mrs. White and C. Willis. The White quarry consists of a shallow excavation extending over an area of four to five acres. The oölite previously described is here eighteen to twenty inches thick. Above this is a thin bedded, light colored dolomite and beneath is a more compact brittle variety. Lime was at one time burned here. In the Willis quarry the oölite also appears and a compact drab dolomite, streaked horizontally with bands of faint blue. The excavation is here eight to ten feet deep. In the Ferguson quarry the upper bed is much fissured and broken into angular fragments, which are recemented into a breccia. It is interesting to note that this breccia occurs at the same horizon as that seen in the quarry of the Monroe Stone Company, and the layer exposed at Stony Point (see Plate XII). Beneath the brecciated stratum there is a compact, bluish-gray dolomite. To the northwest from this group of quarries about one-quarter to one-third of a mile occur two others. One belongs to Elisha Sorter and is located in the N. E. ¼, N. E. ¼, Sec. 16, upon the ridge. This is a small triangular opening from which rock has been taken to a depth of three feet and burned into lime. The dolomite here is compact, bluish-gray and contains numerous fossil casts and moulds. To the naked eye and still better under the magnifier, it shows a very fine crystalline structure the reflections from the minute cleavage faces causing it to sparkle. Some 200 paces west a small test opening was made into the same beds and a second about 130 paces to the south, the latter showing the oölite. In the S. W. ¼, S. W. ¼, Sec. 10, upon the land of William Dunbar an irregular quarry has been opened in a meadow 100 paces east of the residence. The main rock shown here is the oölite with a small amount of overlying dolomite. One-quarter mile north similar rock has been removed from a ditch. In the N. E. ¼ of Sec. 21, a small quarry has been opened upon the road side by George Carr. Two to three feet of the bed are exposed showing it to be a thin-bedded and shattered faintly-streaked dolomite.

§ 15. Whiteford quarries.

There remain but two small quarries to be briefly described and these are located in the southern part of Whiteford township. Those lying above the Sylvania sandstone have been described in a previous section of this chapter. In each of these two quarries the oölitic stratum occurs in a peculiarly modified form, termed locally "bastard limestone." This is best seen in the quarry of Nelson Bush in the S. W. ¼, S. E. ¼, Sec. 25, just north of the east and west road. The rock here seems much disturbed and broken and suitable only for road work, for which it has been used. At the time of the visit a portable crusher was at work preparing stone for a road leading into the city of Toledo. The uppermost strata consist of a very compact bluish-gray dolomite which passes into the oölite, both forming a bed five to six feet thick. Beneath lies a gray compact bed which has been entered but a short distance. East a few rods considerable rock has had to be blasted from the bed of Bay Creek, in order to suitably deepen it for drainage purposes. Large blocks of the oölite and compact dolomite are found upon the bank, along the stream, for a considerable distance.

The second quarry of this group belongs to Stephen Young and is situated in the N. E. ¼, N. E. ¼, Sec. 4 (T. 9 S., R. 6 E.) about twenty-five rods northeast of the residence. The excavation is an irregular quadrilateral about fifty feet long and has a depth of five feet. Near the center of the quarry the rock strata are said to have been horizontal but about the sides appear much disturbed. The rock is the compact, modified oölite of a buff color and gritty feel, so that it is easily mistaken for a sandstone, upon superficial examination.



1250 S. Bluish grey, somewhat ferruginous shales, slightly effervescing.

1400 S. Bluish grey, somewhat ferruginous shales, slightly effervescing, with minute granules of quartz.

1570-1655 S. Green and red ferruginous shales, slightly effervescing, with a trace of magnetite.

1655-1735 Next above Trenton, S. black bituminous shale, effervescing slightly, fusing with an aromatic odor and intumescence to a blebby enamel; a little finely divided quartz.

1734-1740 First screw in Trenton. S. Buff colored dolomite; hard, with slow effervescence. At 1742 gas, odorless with white flame; considerable salt water?
1745-1750 Third screw in Trenton. S. } Both buff colored limestone.
1750-1765 4th, 5th and 6th screw in Trenton. S. }

ABBREVIATIONS.

S. is placed after points from which samples are taken.
S. M. From all the points thus marked one mixed sample was obtained.
S. M. S. Beside the mixed sample there is also an individual sample.
S. B. refers to depths in the well at South Bend, Indiana.

CHAPTER V.

PHYSICAL GEOGRAPHY.

§ 1. Climate.

The geographical position of Monroe county, its proximity to Lake Erie, its topography, and the prevailing direction of wind combine to make it one exceptionally favored so far as productive climate is concerned. It corresponds, in all essential particulars, with the noted fruit belts of western New York and northern Ohio. Lying low and flat, hemmed in on the west and northwest by morainic ridges, with the great body of water, which forms its entire eastern boundary, slowly radiating its summer heat, fall frosts are delayed sufficiently for crops to mature. Upon an average, not until October 12th does the first killing frost occur in the center of the county. During the past ten years the earliest date at which this has occurred was Sept. 21st and the latest was Oct. 30th. During the greater part of each year the wind blows from the quarter of the compass lying between south and west, as will be seen by examining Tables II and III. In consequence, the mean temperature is higher than it might otherwise be and the annual precipitation is abundant. According to statistics published in Walling's Atlas of Michigan by Dr. A. Winchell, the average annual precipitation at Monroe for eighteen years (1853 to 1870 inclusive) was 31.8 inches, with a minimum of 26.17 inches. This was distributed through the seasons as follows: spring, 8.11 inches, summer, 9.85 inches, fall, 8.27 inches, winter, 5.56 inches. During the past twelve years at Grape the precipitation has averaged about three inches less being 28.724 inches. At Toledo where approximately the same weather conditions prevail, as in the southeastern part of Monroe county, the mean annual precipitation for the past twenty-nine years is 30.68 inches, rather evenly distributed throughout the year as will appear from an inspection of Table IV. During the winter months, of course, some of this is precipitated as snow, ten inches of which are regarded as equal to one inch of rain. The average snow-fall

TABLE. II.—ANNUAL CLIMATIC DATA, GRAPE, MONROE COUNTY, MICH.—J. W. MORRIS, OBSERVER.

Year.	Temperature.					Precipitation expressed in inches.				Frost.	Wind.
	Mean annual.	Highest.	Date.	Lowest.	Date.	Total annual.	Greatest in 24 hours.	Date.	Total snowfall.	First killing frost in fall.	Prevailing direction of wind for the year.
1888						23.99	1.60	November 11	22.5		
1889						31.50	1.35	March 31	24.3		
1890	49.4	99	June 4	0	March 6	30.44	2.92	August 21	35.1	October 21	West.
1891	50.0	96	August 9	3	February 4	25.77	1.12	November 10	27.2	October 30	West.
1892	48.4	95	July 24	-18	January 20	36.82	2.94	September 13	31.4	October 24	West.
1893	47.9	94	July 25	-10	January 14 and 15	27.40	1.83	October 3	59.7	September 26	West.
1894	50.0	96	July 19	— 8	February 24	27.41	2.35	September 5	30.0	October 14	Southwest.
1895	47.5	94	*	-14	February 5	20.66	1.95	December 19	59.9	October 21	Southwest.
1896	49.4	97	August 9	— 8	February 17	30.73	1.87	July 26-27	33.5	September 23	Southwest.
1897	49.1	98	July 4	— 9	January 25	30.98	2.05	July 26	37.5	September 21	East.
1898	49.99	98	September 2	— 5	February 3	32.43	1.41	March 19	32.5	October 26	Southwest.
1899	49.7	98	August 11, 19	—15	February 10, 13	26.56	1.13	December 11-12	34.6	Sept. 30, Oct. 1.	Southwest to west.
Average	49.14	96.5	July 27	— 8.4	February 5	28.724	1.88	September 1	35.7	October 12	Southwest.

*June 3, July 16, August 10 and September 11.

at Toledo for the past fifteen years has been 33.6 inches, the greatest fall occurring during the winter of 1895-96, giving a total for that year of 63.7 inches. The least snow-fall during this period of years occurred during 1889-90 when there fell the surprisingly small amount of only 6.0 inches. For the past twelve years at Grape the amount is slightly in excess of the Toledo average, as would be expected. Here it has averaged 35.7 inches, with a maximum in 1895 of 59.9 inches and a minimum in 1888 of 22.5 inches. It is evident from these figures that even during winters of greatest snow-fall the bulk of the moisture received from the air is precipitated as rain. During the twelve years over which records have been kept at Grape, located near the center of the county, the maximum amount of rain-fall in twenty-four consecutive hours equaled 2.94 inches and this fell Sept. 13th, 1892. This was nearly equaled on Aug. 21st, 1890, when 2.92 inches fell.

TABLE III.—ANNUAL CLIMATIC DATA, TOLEDO, OHIO.—RECORDS OF THE U. S. WEATHER BUREAU.

Year.	Mean temperature.	Total precipitation in inches.	Total snowfall in inches.	Prevailing direction of wind.
1871	49.5	31.38		Southwest.
1872	48.1	27.56		Southwest.
1873	49.3	35.52		Southwest.
1874	50.1	25.83		South.
1875	46.4	28.03		Southwest.
1876	49.0	34.55		Southwest.
1877	50.7	35.17		Southwest.
1878	51.8	32.67		West and northeast.
1879	50.4	30.27		Southwest.
1880	52.0	35.72		Southwest.
1881	51.6	45.91		West.
1882	51.1	33.03		South.
1883	48.6	34.24		South and southwest.
1884	50.0	28.43		Southwest.
1885	47.0	33.19	41.9	Southwest.
1886	48.1	32.70	51.9	Southwest.
1887	48.9	32.01	36.2	Northeast and southwest.
1888	47.6	25.86	25.2	Southwest.
1889	49.8	21.84	18.7	Southwest.
1890	50.7	33.64	22.9	Southwest.
1891	50.3	27.12	26.7	Southwest.
1892	48.6	36.70	30.1	Northwest.
1893	48.3	23.81	44.9	Northwest.
1894	51.1	21.34	20.9	Southwest.
1895	48.2	25.31	58.6	Southwest.
1896	50.0	33.10	44.5	Southwest.
1897	49.6	30.35	31.5	West.
1898	51.0	28.10	20.9	West.
1899	50.0	27.06	28.4	Southwest.
Average	49.6	30.68	33.6	Southwest.

Of still greater importance to the agricultural interests of the county is the question of temperature, particularly its distribution through the year and the minimum reached during the winter. At

Grape for the last ten years the mean annual temperature as determined by standard instruments has averaged 49.14°, while at Toledo for the last twenty-nine years this average has been 49.6°. So far as we may judge from our data the minimum is most liable to be reached during the first week in February, but may range from the middle of January to the first week in March. The lowest temperature reached at Grape since 1890 was 18° below zero, Jan. 20th, 1892. The highest temperature recorded for this period was 99° on June 4th, 1890; unusually early in the season, the maximum averaging the last week in July. The summer isotherm of 70°, which marks the theoretical position of the sugar beet belt, cuts diagonally across the county. The distribution of the heat and moisture over the year is shown quite satisfactorily in Table IV, based upon the records taken at Toledo by the U. S. Weather Bureau.

TABLE IV.—AVERAGE MONTHLY TEMPERATURE AND PRECIPITATION, 1871 TO 1899.

Month.	Temperature.	Percipitation.
January	25.8°	2.03
February	27.8	2.02
March	34.8	2.23
April	47.6	2.19
May	59.2	3.39
June	69.1	3.29
July	73.1	3.10
August	70.7	2.60
September	64.0	2.38
October	52.4	2.32
November	39.6	2.84
December	30.6	2.29

TABLE V.—ANNUAL CLIMATIC DATA, TOLEDO, 1860-1869.

Year.	Mean temperature.	Maximum temperature, F.	Minimum temperature, F.	Total precipitation.
1860	49.343°	94°, Aug. 6	—10°, Jan. 2	
1861	50.368	96°, Aug. 2	— 4°, Feb. 8	36.4660 in.
1862	51.732	97°, July 6	— 2°, Feb. 15	42.9980
1863	51.069	95°, Aug. 5	6°, Feb. 3	32.6370
1864	49.987	98°, July 28	—15°, Jan. 1	37.1545
1865	49.639	94°, July 6	— 1°, Jan. 11	39.3120
1866	47.994	95°, July 16	—16°, Jan. 16	40.6878
1867	48.819	94°, July 23	— 6°, Jan. 14	31.0620
1868	47.761	100°, July 14	—10°, Feb. 3	42.9375
1869	48.512	95°, Aug. 20	3°, Feb. 28	42.2500
Average	49.554°	95.8°, July 25	—5.5°, Jan. 26	38.9087 in.

In the first volume of the Ohio Geological Survey the observations of Dr. J. B. Trembly are published in the form of two tables. These were taken at Toledo from Jan. 1st, 1861, to Dec. 31st, 1869,

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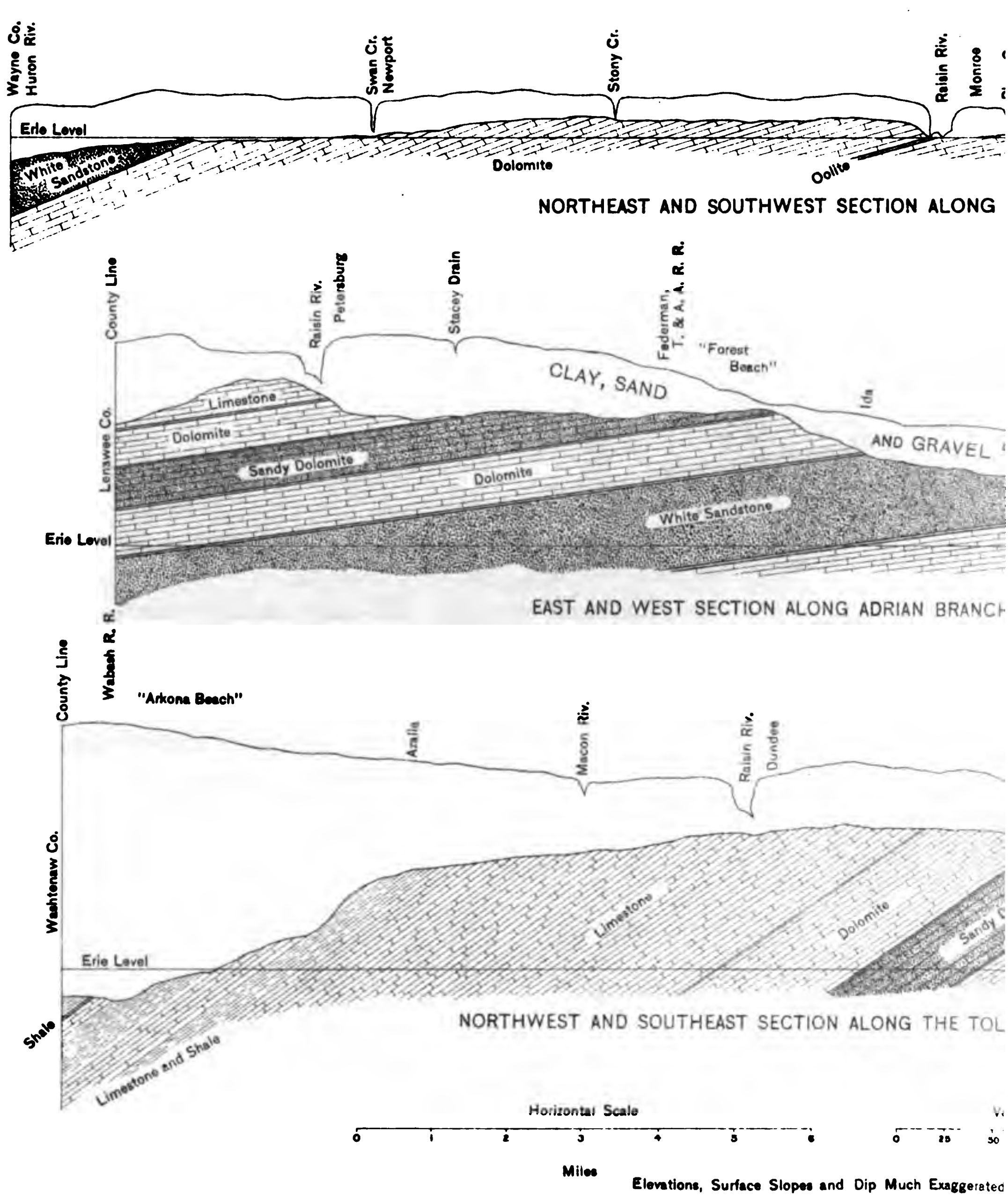

W. H. SHERZER, Fecit.

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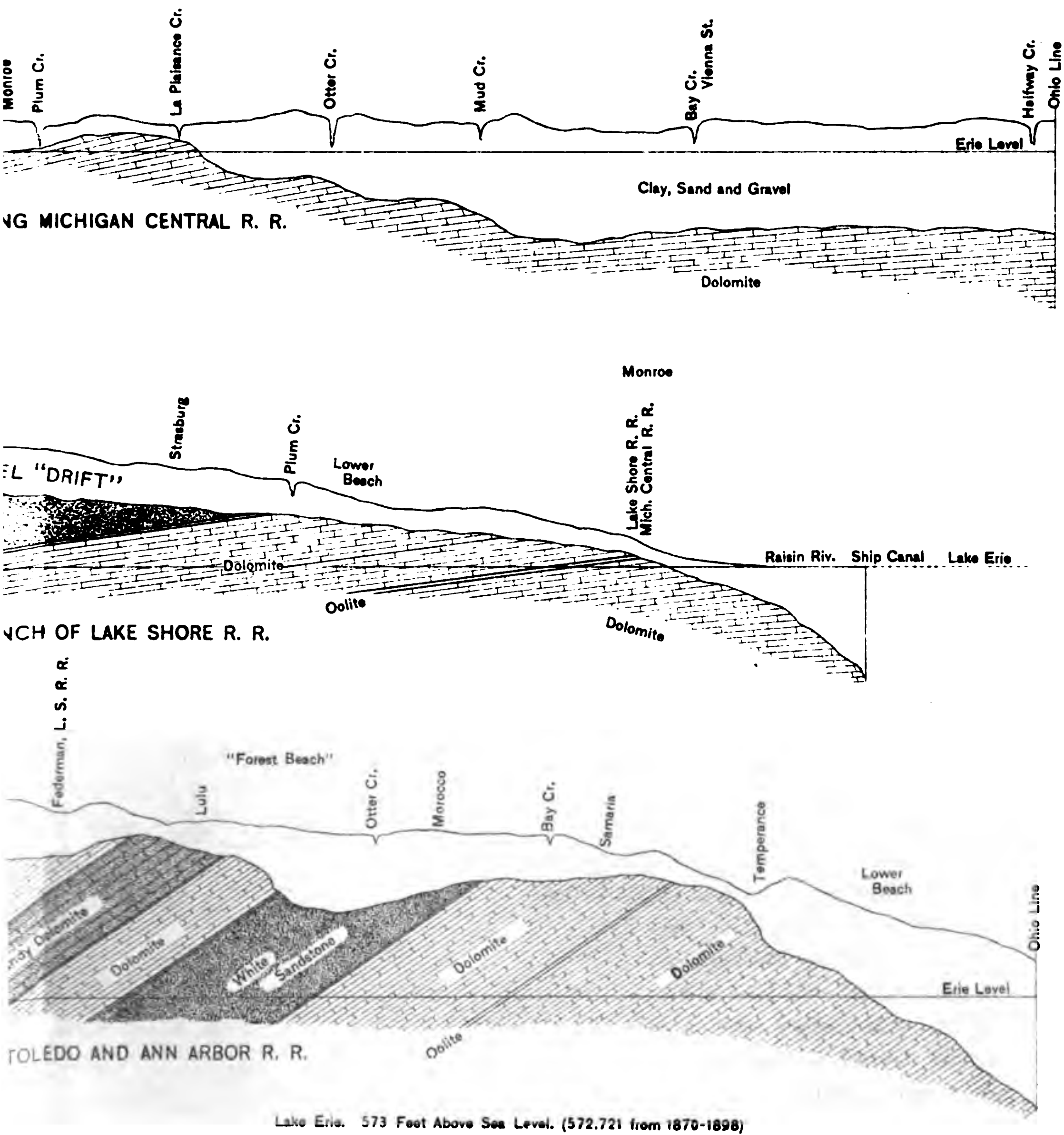

NG MICHIGAN CENTRAL R. R.

NCH OF LAKE SHORE R. R.

TOLEDO AND ANN ARBOR R. R.

Lake Erie. 573 Feet Above Sea Level. (572.721 from 1870-1898)

Surface Elevations from Railroad Levels,

Rock Elevations from Individual Well Records.

rated.

GRAND RAPIDS LITHO CO

and may be assumed to approximately represent the meteorological conditions that prevailed in Monroe county during this decade. Table V is compiled from these statistics and contains the more important data. It is interesting to notice that the rainfall is much in excess of that recorded from 1888 to 1899, and the lake level was higher at that time. Compare Plate V of Part II of this volume.

§ 2. General configuration of the county.

If it were not for the local mounds and irregular ridges which characterize the sand hills indicated on Plate VII, as well as the eroded stream valleys, the entire county would present the appearance of nearly unbroken horizontal plain. From the northwest corner, towards the southeast, there is an average downward slope of about seven feet to the mile, but this is imperceptible to the eye. A very gentle rise marks the position of the "stony ridge," extending from Sylvania to Stony Point, and varying in width from one-half mile to one mile. This peculiar flat effect has been produced by wave action, which cut down the natural eminences and filled in the depressions, thus grading the surface of the county until it retained barely enough slope for its own drainage. The irregularities above referred to as now to be seen, have been impressed upon the surface in a way to be presently described, after this wave action over the region affected had ceased. Upon Plate VI there is shown a series of vertical sections, across the county, along the line of the railroads, based upon the profiles of these roads and numerous well records. The upper section is along the Michigan Central, at right angles to the general direction of the surface slope, and shows the remarkably level character of the county when taken parallel with the lake shore. The lower section is along the Ann Arbor R. R. and the middle along the Adrian-Monroe branch of the Lake Shore, each cutting the direction of the slope at about 45°. The inclination of the surface is greatly exaggerated, however, by the vertical scale adopted, in order to bring out the irregularities. An inspection of these diagrams shows that the surface slopes more gently down to the broad sand belt, known as the Forest Beach, and then more rapidly to the present shore of the lake. The average grade within the limits of the county, along the Lake Shore road is 5.5 feet to the mile, and along the Ann Arbor about 4 feet.

§ 3. Elevations within the county.

Data relating to altitudes have been procured from four different sources, more or less reliable, and from these it has been possible to construct a map (Plate VII) upon which the approximate elevations are represented by a system of contour lines, drawn at intervals of ten feet above mean tide level (A. T.) at New York City. This would not have been possible in a county with broken surface features, without a much more accurate topographic survey. The contour lines must be regarded as only approximately located and are much smoother than they would appear if determined by detailed work with a spirit-level. Over the sand areas no attempt was made to represent the position of the numerous mounds and ridges of blown sand. These are frequently rapidly changed through the agency of wind and water and ordinarily their height falls within the contour interval. Upon each contour line its elevation above Lake Erie is placed in parenthesis.

(a). U. S. Survey levels. For all practical purposes the elevation of Lake Erie at the present time may be taken as 573 feet. The mean elevation for the period 1870 to 1898 is more accurately 572.721 feet. The highest level of which there is definite record was reached in 1838, when it equaled 575.2 feet; the lowest was attained in November, 1895, being then but 570.79 feet. During this sixty years the fluctuation has been 4.41 feet, enough to produce a marked effect upon the low-lying shores of the lake. Within the memory of the older residents flat-bottomed boats were loaded where now the land is under cultivation. The Board of Engineers of the Deep Waterways Commission has recommended the regulation of the lake level by the construction of weirs at the foot of the lake just below Buffalo harbor, so as to maintain a level of 574.5 feet, and insure a sufficient amount of water for navigation purposes in the fall when the traffic is greatest and the water liable to be lowest.

A geodetic station is located in the cemetery of the Monroe county Poor Farm, about four miles west of the city, the elevation of which has been confused with that of the city itself. The geodetic point is a small hole drilled in the top of a stone post set in the ground, the elevation of which at the base of the post is 43.9 feet above the mean level of Lake Erie. This mean level referred to is one that was earlier determined than that given in the above paragraph and equaled 572.86 feet. The elevation of the land then at the point indicated is 616.76 feet above tide. A second station, the elevation of which has been determined with some accuracy, lies between Dundee and Petersburg, south of the Raisin. This was also a geodetic station marked with a stone post and three reference posts. It is located in the extreme N. W. ¼, N. W. ¼, Sec. 36, Summerfield township T. 6 S., R. 6 E., on the northwest side of the diagonal road leading from Dundee to Petersburg. One reference post bears N. 76° 51′ E. and is 22.4 meters distant; a second bears S. 4° 49′ E., distant 17.55 meters. These two lie on the northwest side of the road, while the third is upon the southeast side, bears S. 18° 53′ E. and is distant from the geodetic point 34.05 meters.

The corner of Secs. 25, 26, 35 and 36 bears N. 87° 32′ W. and is 110.25 meters distant. The elevation of the ground at this point is 681 feet. A photolith copy of the Toledo topographic sheet, now being prepared by the U. S. Geological Survey, has been received during the final stage in the preparation of this report. It gives the contours of 600, 620, 640, 660, 680 and 700 feet above mean sea level for the region to the north and west of Toledo and continues them into Michigan for a distance of one and one-half to two miles. There is thus furnished an accurate and very important check upon the work based, in the main, upon railroad levels.

(b). Railroad levels. In the construction of the contour map, referred to above, reliance had to be placed mainly upon the series of railroad levels, very kindly supplied by the roads which intersect the county in so many different directions. Assuming that the profiles of these roads were approximately correct it was found that they could not be adjusted to one another with the datum plane given by the various offices; wide discrepancies appearing in the elevation of the same point. For various reasons it is best to explain here how this adjustment was made. It seemed most desirable to settle first a datum for the Lake Shore system, with its branches, with reference to lake level. The county surveyor, Mr. A. F. Winney, of Monroe, has determined that the top of the rail on the bridge at the Raisin is 19.4 feet above bed rock in the river beneath. The profiles of this branch of the road shows the rail here to have an elevation of +17 feet and that of the bed —2. The water has here become stagnant and if we assume a few inches of deposit upon the rock the figures are in agreement. Owing to the drowned condition of the mouths of all the rivers which empty into the lake, the level of the Raisin here represents approximately the mean level of the lake, and is so considered in the Michigan Central levels. The figures obtained from the Lake Shore office then are regarded as elevations above mean Erie level and, upon this supposition, are in substantial agreement with those of the Michigan Central and the Pere Marquette, referred to the same datum.

In the case of the Ann Arbor road two sets of elevations were obtained about a year apart. In one case the datum was given as the mean level of Lake Michigan (582 feet) and in the second case was stated to be unknown. At its junction with the Adrian-Monroe branch of the Lake Shore, according to the profile of the latter road, which is assumed to be practically correct, the elevation of the rail is 93.07 feet above Lake Erie level. With Lake Michigan level as a datum the profile of the Ann Arbor road gives the same point an elevation of 112.4 feet above Lake Erie. The profile of the road was assumed to be approximately correct within the limits of the county, the actual elevation of the junction with the Lake Shore, at Federman, was regarded as 93 feet above Lake Erie and the difference adjusted along the line in either direction. This brings these elevations into substantial agreement with those of the Pere Marquette, in both the southern and northern part of the county through the Detroit and Lima Northern. In the case of the latter road the datum could not be secured, but the series of actual elevations was obtained similarly by knowing the elevation of its junction with the Pere Marquette at Carleton. Upon the above basis the approximate elevation of the rail at the following stations has been computed. The elevation above mean sea level may be obtained by adding 573 feet to each. Most of them

TABLE VI.—ALTITUDES OF RAILROAD STATIONS.

(Approximate elevation of rail above Lake Erie.)

	Feet.		Feet.		Feet.
Azalia	102	Monroe—		South Rockwood—	
Carleton	41	Michigan Central	15	Michigan Central	14
Cone	141	Lake Shore	16	Lake Shore	16
Dundee	95	P. M	28	Steiner	41
Federman	93	Morocco	79	Stony Creek -	
Grafton	41	Newport—		Michigan Central	21
Ida	70	Michigan Central	18	Lake Shore	24
LaSalle—		Lake Shore	19	Strasburg	53
Michigan Central	15	Ottawa Lake	119	Temperance	46
Lake Shore	17	Petersburg	105	Vienna—	
P. M	25	Rea	116	Lake Shore	13
Lulu	83	Samaria	71	Michigan Central	13
Maybee	61	Scofield	52	P. M	24
Milan	122				

will be found to differ materially from those given in Gannett's table of railroad elevations.*

(c). Elevated beach levels. At periods when the waters of the Great Lakes stood at successively higher levels a series of beaches was impressed upon the surface of the county. These beaches thus mark actual physical contours, the approximate elevations of which are known from outside data. Their position is indicated upon Plate VII, where they furnish a check upon the accuracy of the work based upon the railroad levels. These beaches will be described in another connection and it may simply be said here that the highest marks the altitude of 170 feet above the lake, the second that of 121 feet, the third about 85 feet and the lowest about 42 feet.

(d). Aneroid levels. By means of an aneroid barometer a great many readings were taken in the course of the survey upon railroads, well curbs and rock ledges. Except where the points were near together, and but a short time elapsed between readings, no great reliance could be placed upon such determination of difference in elevation. Some of this material has been used in making up the body of this report. The barometer was found chiefly serviceable in getting the approximate height of the river terraces and banks, where these could not be measured directly. The northwestern corner of the county was found to be four feet lower than the "gravel ridge," which constitutes the 170 foot beach referred to above, and so has an elevation of 166 feet above Erie level. This beach which cuts diagonally across the N. W. ¼, Sec. 6 of Milan, is the highest strip of land within the county and functions as a minor watershed. Although a great deal of accurate levelling has been done in connection with the numerous drains, there is but little of it utilizable. The lines of levels run for but short distances and are entirely disconnected.

§ 4. Surface drainage.

A glance at the map of the county shows that the drainage is, in general, southeastward and from what has been said in regard to the surface slope it is apparent why this should be the case. Consult "Water Resources of the Lower Peninsula of Michigan." Lane, No.30 of the Water Supply and Irrigation Papers of the U. S. Geol. Survey, 1899, especially p. 62. Most of the streams make their way independently to the lake and are not united into a system, so as to form a central stream of some magnitude. The Raisin is the largest and most centrally located river but the greater part of its water it possesses upon entering the county. This has been obtained from the eastern part of Lenawee, the southwestern part of Washtenaw and the southeastern part of Jackson counties. Measured in a straight line the river is about 80 miles long but this is increased several times over, by the great amount of meandering. Owing to the very even surface slope the streams which might have become tributary to the Raisin continue their course to the lake. This is well illustrated by Plum Creek which rises within a mile of the Raisin, and for fully 18 miles flows parallel with it, entering the lake separately. At no time does it get beyond three miles from the main stream, approaches to within two-thirds of a mile for a short distance, without breaking through, and then continues lakeward for a dozen miles further. North of the river there are some minor tributaries which join it finally, only after paralleling it for a number of miles. Following the Raisin upon the south side and along many of the other streams there is more or less sand deposit outside of the main valleys. This was probably deposited as a delta upon either side of the stream as the waters of the lakes were gradually withdrawn from the land.

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*Bull. U. S. Geol. Sur., No. 76, 1891.

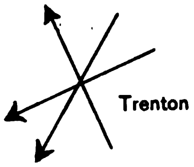
Two streams worthy of the names of rivers, do enter the Raisin, however, in the southeastern part of Dundee township, the Macon and the Saline. These streams appear to have had a common bed from this point to the lake. From their point of union a broad depression extends southwestward for a number of miles into Lenawee county as shown by the surface contours. It is quite probable that this depression was occupied by a third small stream which also joined the Macon and Saline. The natural direction of the Raisin is southeastward across Lenawee county, but it takes a very abrupt turn and enters Monroe county flowing northeastward across Summerfield and Dundee townships. It seems very probable that this third stream referred to cut its way back into the watershed which separated it from the Raisin, until the latter stream was tapped and "captured." This bed furnishes a more direct route to the lake and the Raisin turned northeastward until it reached the common bed of the Macon and Saline. This bed was also appropriated, since it furnished a direct course across the two lower beaches and the Macon and Saline became tributary to the Raisin while the third stream was obliterated.

As the river swings from side to side there is cut out of the drift deposits which cover the rock, a broad valley partly filled with river silt. During times of highest flood the river leaves its channel, spreads over all the region between the outer banks, and as the velocity of its water is checked, there is deposited a layer of sediment. In the course of time there is built up a flat terrace, the height of which is determined by the height to which the water may rise at each particular part of the stream. This constitutes the flood-plain of the river. In the case of the Raisin it may be followed from near the lake, continuously up stream, across the county. Where the valley is broad and the river has a chance to spread most during flood its height is less. On the other hand where the valley is narrowest, the flood-plain terrace is highest, as is well shown at Petersburg. Here the valley, which is ordinarily from one-quarter to one-half mile in width, narrows to about 700 feet and the terrace is fully eight feet above the general level of the river. In the western part of the county the banks vary from twenty to thirty feet above the bed of the stream, are 26 feet high at Dundee and gradually diminish towards the mouth.

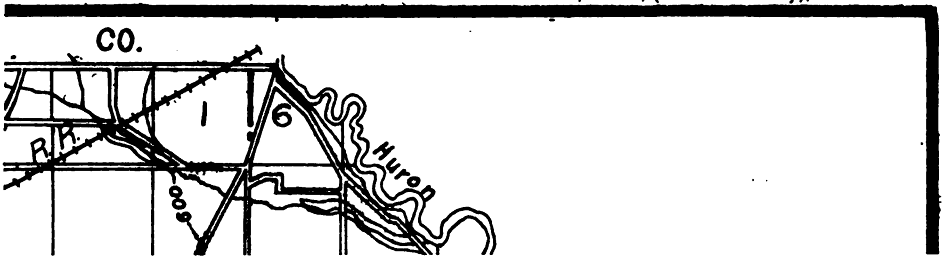
For each individual stream there seems to be a limit to the amount of wandering of which it is capable, and hence to the breadth of its valley. In the formation of the great ox-bows a neck of land is produced into which the stream cuts on opposite sides until it is completely eaten across and the channel is straightened. The abandoned portion of the bed forms a crescent shaped marsh or lagoon, numerous examples of which may be found along nearly all of the streams. The erosive action of the water is thus confined mainly to the terrace deposit of its own making, rather than to the valley banks and this is torn down and built up many times over in the history of the river. In places, however, new work is being done upon the original drift deposits and the valley correspondingly broadened until the stream is again straightened and the water withdrawn. Besides the one above mentioned, other factors contribute to the periodic straightening of the river channel. As the stream cuts laterally into its banks, owing to the deflection of the main current, it forms an ox-bow and its length is correspondingly increased. In one case noted in the Huron, near

Flat Rock, the river has meandered a mile and advanced less than one hundred feet. The actual amount of fall remains the same, while with the great increase in the length of the stream the rate of fall is much diminished. The effect of this decrease in rate is to check the velocity of the stream and to cause it to stand at a higher level at the beginning of the ox-bow referred to. The amount of this damming effect bears a direct relation to the distance which the stream has moved sidewise and tends to prevent its ever exceeding a certain amount for any particular stream. This is because the time arrives when only a slight rise in the stream will cause it to overflow across the narrow neck, and the main current will cut out a straight channel in a few hours. This action may be aided by the surface drainage, which may cut channels across this neck and reaching backward may finally tap the main stream, or form a depression through which the water may more readily find its way. This alternate meandering and straightening of the Raisin has gone on many times. Within the easy memory of the older inhabitants marked changes have occurred in the course of the stream, forest trees of respectable size now growing where there had been boating and fishing.

As has been previously stated rock occurs in the bed of the river just above Petersburg and again at Dundee. At the mouth of the Macon where the water is low, heavily bedded, glaciated limestone ledges project in the bed. For a distance of four to five miles further down the river is deep and sluggish and has a mud bottom. Just above Grape the rock again appears, and then occurs at frequent intervals to Monroe. A view of the river at Monroe is shown in Plate VIII, where the stream is from 210 to 220 feet across, being rendered shallow and broad by the layers of dolomite in its bed. Ice jams periodically form opposite the city by which the river is forced out of its banks. An unusually heavy freshet occurred this past spring (1900) from this cause and another in 1887, by which one of the passenger bridges was destroyed. The fall from the Macon to Monroe is about sixty feet, giving an average of about four feet to the mile, as measured in a straight line. Dams have been constructed at Petersburg, Dundee, Grape and above Monroe and the power of the stream utilized for milling purposes. In conjunction with Plum Creek a well defined delta has been formed between Monroe and the present shore of the lake, consisting of a



Vol. VII, Part I, (Monroe County), Plate VII.



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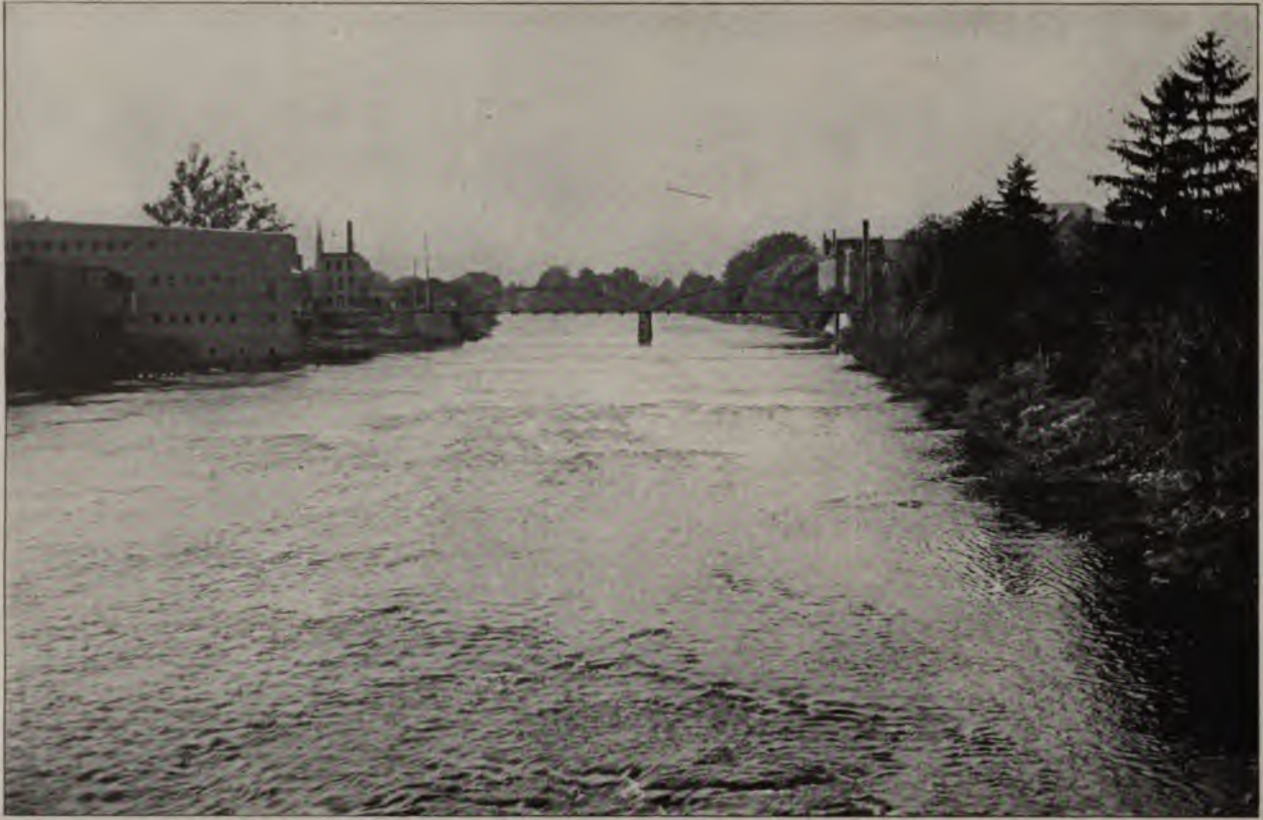


RAISIN RIVER AT MONROE.

low, flat marsh but little elevated above lake level, across which the river reaches the lake by several mouths. While Michigan was still a territory a canal was constructed by the general government through which more direct communication with the lake was established. Work was begun in 1835 upon this canal and the next year the city itself constructed the "city canal" cutting off the ox-bow of claim 653, by which this part of the river was rendered navigable for the lake craft of those days.

The Macon and the Saline rivers, with their branches, drain the northwestern part of the county, the southern part of Washtenaw and the northeastern portion of Lenawee. They are simply the Raisin in miniature, each showing the broad valley, the elevated flood-plain over which they pursue their winding courses. The banks are about twenty-five feet high where they join the Raisin, but gradually diminish to less than half this height.

The Huron forms the northern boundary of Berlin township, but receives no tributaries of any size from the county. It has about the same length as the Raisin and carries nearly the same amount of water. It rises in the western part of Oakland county, flows southwest across the southeastern part of Livingston, between great morainic ridges and through a chain of lakes, taking then a winding southeasterly course across Washtenaw and Wayne and entering the lake just below the mouth of the Detroit river. Rock is encountered in the bed of the stream only at Flat Rock, where it has been quarried to a small extent. The banks here are from fifteen to sixteen feet high and about sixty rods apart with a flood-plain terrace of river silt which varies in height from five to six feet. The stream itself is about ninety feet across and flows with a swift current. From Flat Rock to South Rockwood the river forms numerous characteristic meanders, similar to those above described for the Raisin. At the latter place the valley banks are eighteen feet above the general water level and about 125 rods apart. The same terrace appears as at Flat Rock, sloping upward from the low water channel to the sides of the valley. The stream maintains about the same size throughout this portion of its course to the lake. The banks are gradually reduced in size until in Sec. 23, of Berlin, they are but two feet high and the flood-plain merges into the broad, flat delta. The stream current has here been lost, although two miles from its mouth, and there is simply an ebb and flow from the lake. A strong easterly wind is said to raise the level of the water two feet. The depth of the stream is ten to twelve feet and toward the mouth is reported as in places twenty-five feet. The U. S. Coast Chart shows a depth of ten to sixteen feet. Such a depth in this portion of the stream, where there is practically no current calls for special explanation (Chapter VI, § 13). Between the Huron and the Raisin, Swan Creek, Stony Creek and Sandy Creek enter the lake directly, each with relatively broad valleys and flood-plain terraces. As has been previously pointed out rock is struck for a short distance in the bed of each. South of the Raisin we have an essentially similar set of streams, Plum, Otter, Muddy, Bay and Halfway Creeks being the principal ones. These drain mainly the region that lies east of the Forest Beach, but in the case of the latter stream the surface drainage of Whiteford to the west is brought to the lake. This cuts through the beach one and one-half miles south of Lambertville, being assisted by considerable dredging and blasting. The presence of the Arkona and Forest beaches has considerably interfered with the natural drainage of Whiteford and the southern half of Summerfield townships and has necessitated the construction of extensive artificial drains.

§ 5. Underground drainage.

In the region of obstructed drainage just referred to, nature has in part obviated the difficulty by sending the surplus water to the lake under the beach, instead of over it. Sink holes and subterranean rock channels have been produced by the solution of the dolomite, so that farms are sometimes drained into old wells. In deepening wells which enter the rock it sometimes happens that the entire quantity of water is lost by opening communication with one of these underground channels. It is reported that sometimes running water may be heard by placing the ear to the ground. In the southern part of Sec. 2, of Whiteford, there occur two large depressions, known respectively as the "Big Sink" and "Little Sink." The latter is the site of Cummins' quarry described in Chapter IV, § 15 and shown on Plate III. The "Big Sink" is a large depression, fifteen to eighteen feet deep, one-half mile long and about one-quarter broad. A ditch from the northwest drains into this and in the spring the depression fills to overflowing and becomes confluent with "Little Sink," forming a veritable lake as

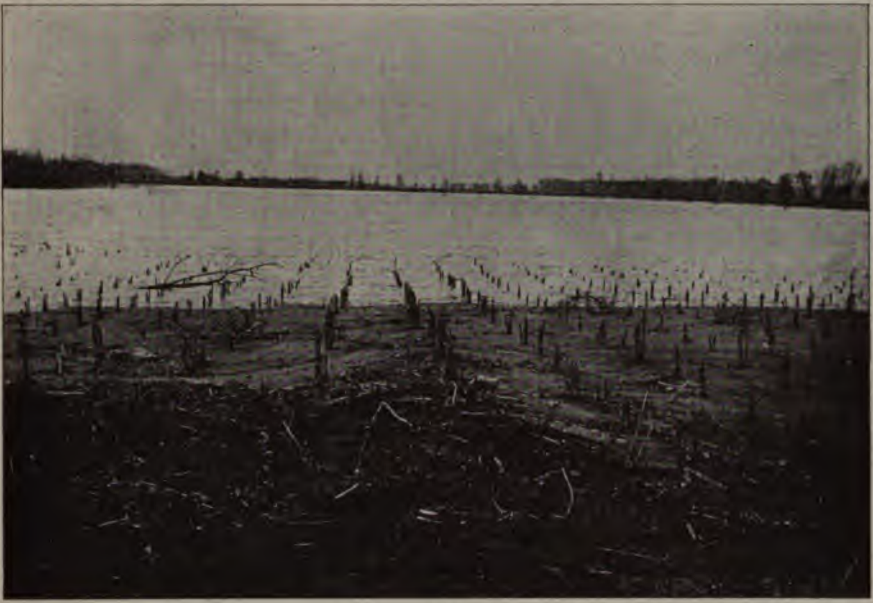


Fig. 2. The "Big Sink" doing service as a lake, March 26, 1898.

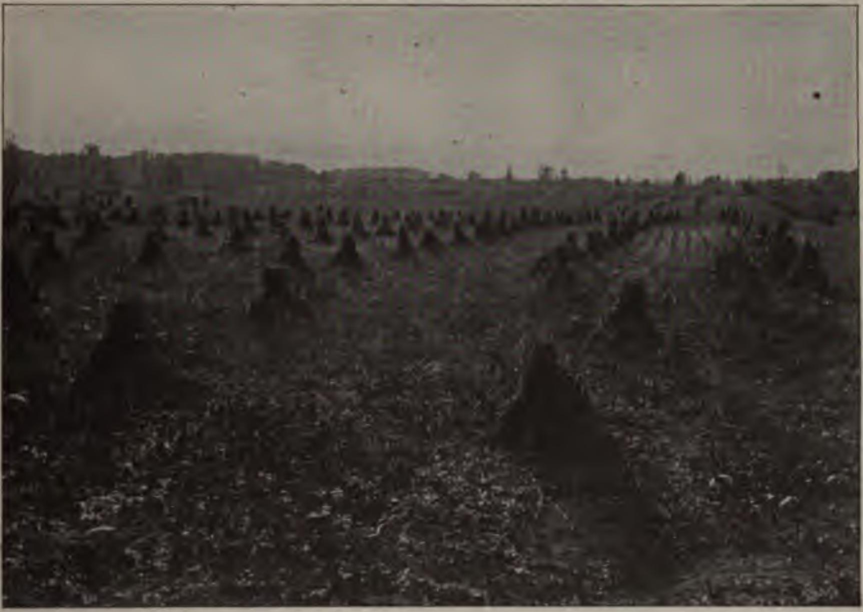
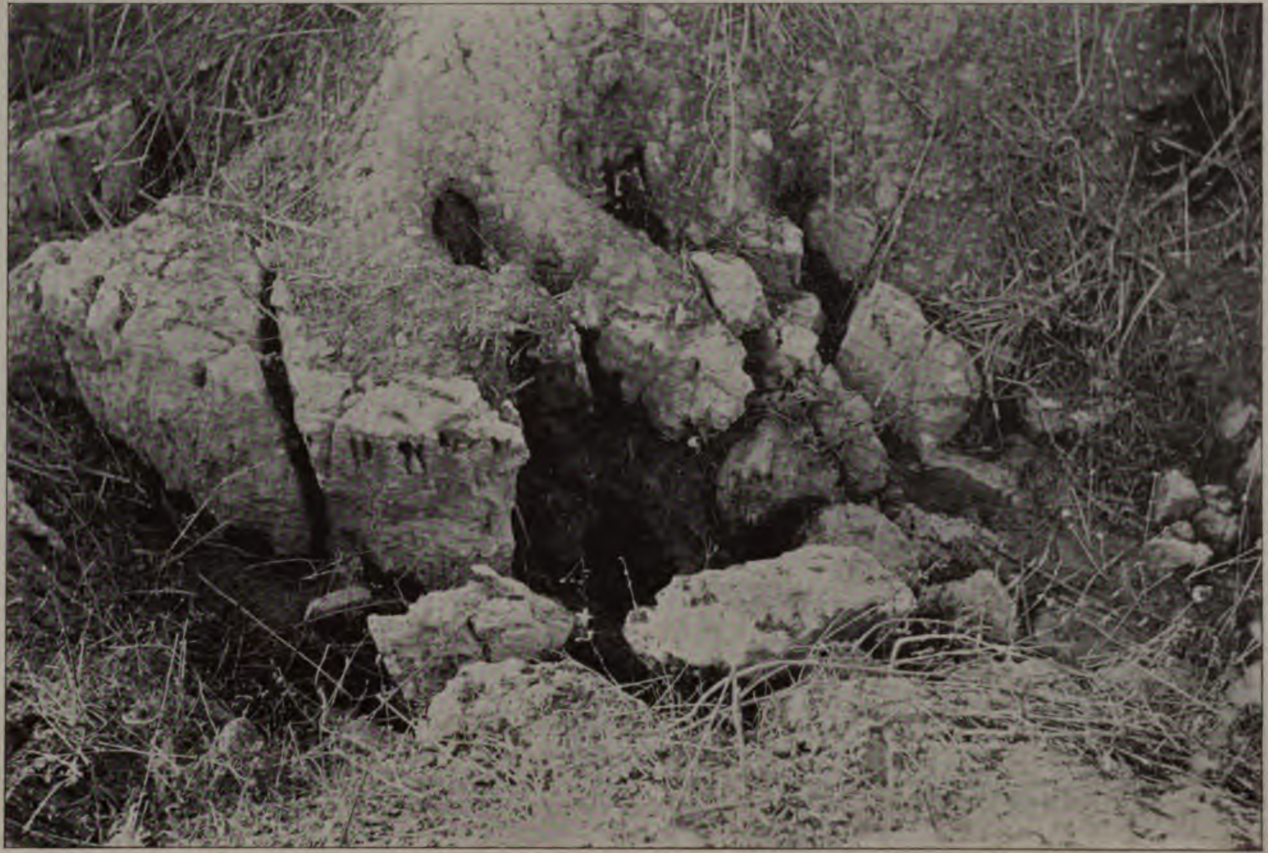


Fig. 3. The "Big Sink" under cultivation, October 15, 1898.

shown in Fig. 2. Each season it becomes stocked with fish from Lake Erie, by means of Halfway Creek, and carp weighing ten to fifteen pounds are said to be caught. In the bottom of the bed there is a small ravine in which occurs the opening shown in Plate IX. Through this the water finally escapes, sometimes very rapidly and with whirlpool effect. It is possible that an ice plug may be formed during the winter and as long as this remains intact the sink retains its water. Whatever the obstruction may be, it is always disposed of in time for the cultivation of the land and Fig. 3 shows the sink in corn. Figs. 2 and 3 were taken from about the same point, one in March and the other in October.

Southwest of these two sinks occurs a much larger one known as Ottawa Lake, lying mainly in Secs. 17, 18, 19 and 20 of Whiteford townships. This has a length of more than two miles and exceeds one-half mile in its greatest breadth, although it is narrow throughout the greater part of its extent. Each season this fills up and becomes stocked with bass, perch, carp and pike as in the above instance. By midfall this lake has practically disappeared, partly by evaporation but mainly through openings into the rock beneath. Plate X shows the bed of the lake, taken from the head looking south, when all the water has gone except the small pool in the foreground. Fish are said to be caught in large numbers as the water subsides, while those left behind to die render the air offensive for some distance. Mr. Edward Montgomery, a local well driller, informed the writer that near the foot of the lake he had seen an opening "as large as a room" leading into the rock and that he had entered it twelve to fourteen feet, but that he could see some distance further and that it contained much mud with fish, turtles and snakes. Search was made last season for this opening but all that was found was a bowl shaped depression in the mud fifteen to sixteen feet in diameter and five feet deep containing about a peck of young cat fish. During the past summer the bed of the outlet has been lowered by the county so that the level of the full lake will be reduced four feet, by which means many acres of marsh land on the south and east will be reclaimed. In the northern part of Sec. 15, Bedford township, there is a small body of water upon the "ridge," known as Little Lake. At the time of Rominger's survey of this region (1873 to 1876) this was dry and showed conspicuous rock crevices in its bed. It has not been dry for a number of years and is not now regarded by local residents as a sink. It seems prob-



ROCK OPENING THROUGH WHICH THE WATER OF THE "BIG SINK" ESCAPES.

able that the subterranean exits have become temporarily clogged and that they may again become functional upon being cleared. A somewhat similar case has occurred just south of the Lulu quarry in Sec. 16, of Ida township, where there is a depression covering five acres and about nine feet deep. This has filled each spring with water which has had to slowly evaporate. In 1896 it appears to have found an outlet, or to have opened a former one, since it was filled several times and each time emptied itself in three days. Just south of the Big Sink, in the N. W. ¼, Sec. 11, Whiteford, there is situated a sink which has become inoperative. Upon the place of Daniel Rabideu there are two small sinks in the S. W. ¼, N. W. ¼, Sec. 10 of Whiteford. In Sec. 8, N. E. ¼, N. W. ¼, there are minor sinks and sink holes, into one of which a man and horse are said to have broken through.

It is very probable that there exists throughout this region a series of underground galleries and chambers, but probably of no great dimensions. The openings are not known to show air currents, which would probably be the case if they communicated with extensive caverns. These subterranean channels seem to extend below the level of the lake and hence must have been cut when the land stood at a higher level. The water which enters these sinks supplies the great springs, which are found to the east along the lake shore. Some of it also very probably reappears in the artesian wells of the region and some of it may reach the lake directly, without coming to the surface.

There is evidence that these underground waters are inhabited by a special fauna similar to that found in caverns. Sometime in the 70's there were pumped from a well in the N. W. ¼, N. W. ¼, Sec. 32, of Summerfield township, three small fish which are said to have showed no trace of eyes. The well was eighty to ninety feet deep and stands upon land now belonging to J. Cosgroy. The fish were seen swimming in a pail by Mr. Ezra Lockwood, who gives the length of the largest as about one and one-half inches, dark brown in color, slender in form, "shaped like a mullet" but with much enlarged paired fins and the dorsal fin extending to the tail. A similar find was reported from Utica, north of Detroit, in Macomb county, some two years ago. Two larger fish were obtained from a well, neither of which according to the owner, showed any trace of eyes. Very unfortunately a cat made a meal of them before they could be secured by the writer. Similar discoveries may be expected in the future and it is to be hoped that the material will fall into friendly hands.

§ 6. Diagonal features.

In 1873 Dr. Alexander Winchell read a paper before the American Association for the Advancement of Science entitled, "The Diagonal System of the Physical Features of Michigan."* Attention was here called to the frequency with which the directions, intermediate between the cardinal points, enter into the physical features of our southern peninsula, and Monroe county might have been selected as a type locality. The far reaching influence of geological forces is well shown in tracing to its cause this diagonal system. The reader will recall the frequency with which the terms northeast, northwest, southeast and southwest have appeared in this report, it being almost impossible to point out a single natural feature in which this diagonal character is not apparent to a greater or less extent. The southeasterly slope causes the streams to take this general direction, the only exceptions being the Raisin, the south branch of the Macon and Halfway Creek. When these streams are not flowing southeast they are, however, flowing northeast. The present Lake Erie shore, the ancient beaches, the sand and clay belts, the outcrops of rock, the belts of artesian water and gas, all have a northeast and southwest direction. The lines joining places of equal elevation, of equal temperature, of equal rainfall and even the prevailing direction of the wind, are diagonal in the county. In consequence of the above facts the distribution of the natural flora and fauna partakes of the same character.

In the days of early French occupancy each claimant of government land was allowed any amount, up to 640 acres, for the surveying of which he was willing to pay. With no system of roads yet established the streams were the highways and each farm must have its water front. The claims were laid out at approximately right angles to the Raisin, Stony, Plaisance and Otter Creeks and what they lacked in width they made up in length, as is apparent from an inspection of the map. For mutual protection, social intercourse, water and fish, the houses were located near the streams and faced them. When the settler went to or from his work, after

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*American Journal of Science, 3d series, Vol. VI, page 36. See also "Michigan," extracted from Walling's Atlas, page 32.

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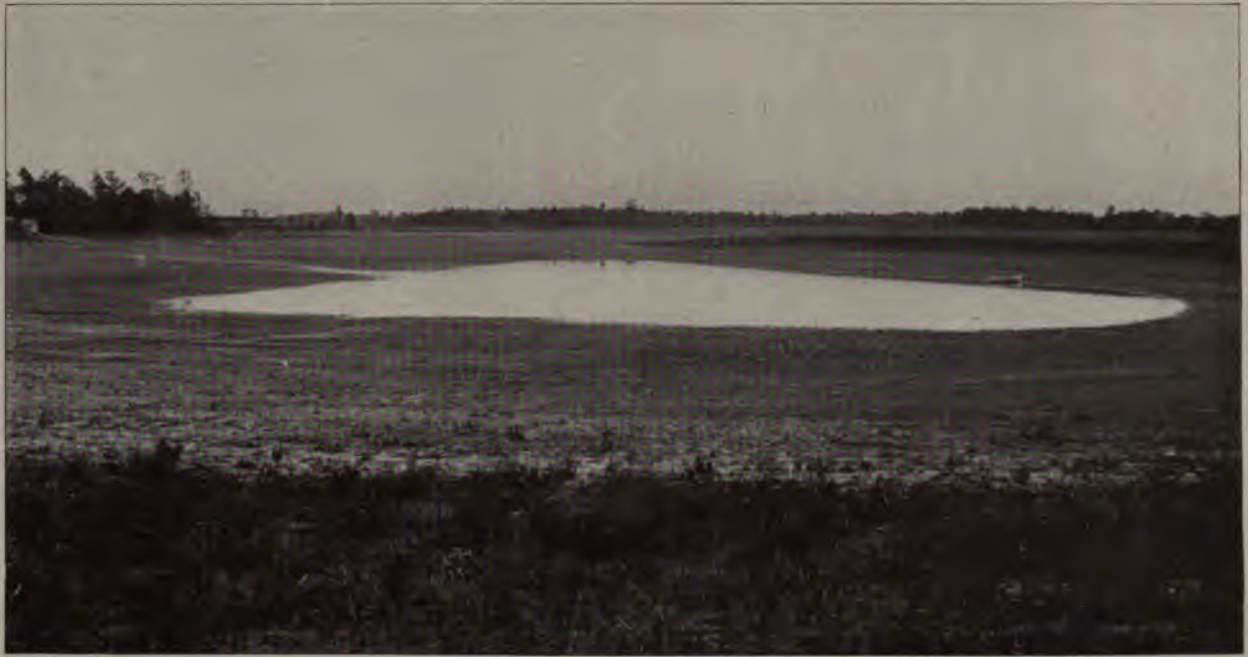

BED OF OTTAWA LAKE (SINK), LOOKING SOUTH FROM HEAD, OCT. 15, 1898.

game, to the traders or to visit his neighbor, he moved, in general, parallel with, or at right angles to the stream. The activities of the home itself were similarly directed largely by the southeasterly course of the rivers and creeks. Later when roads were established they were laid out between the claims, or so as to cut directly across them at certain distances back from the river front and in the eastern and central parts of the county many of these diagonal roads still remain. As the settling of the country progressed the gravel and sand ridges of the beaches were utilized for roads. The old territorial road from Pontiac to Adrian, laid out in 1832, occupies the crest of the Belmore Beach for many miles. The farmers select these higher ridges as sites for their dwellings, because of their accessibility, better drainage and the ease with which water can be secured. For the same reason school houses, churches and cemeteries are frequently similarly located. For over a hundred years a large proportion of the residents of the county have moved, eaten, slept, worshipped and now lie buried upon the bias. When the farmer's son began business for himself he desired the same conditions to which he had become accustomed on the homestead, and these he found by migrating either northeastward or to the southwest. The topography has determined the position of the larger lakes and rivers of southeastern Michigan. These have, in turn, determined the sites of our larger cities, and between the cities run the railroads, which with but one minor exception cut the county diagonally. Along the lines of these roads have sprung up nearly all the villages of the county.

So long ago that the time cannot be expressed in years certain internal forces of the earth disturbed the originally horizontal beds of shale, limestone, dolomite and sandstone. These were tilted so that they dipped to the northwest in this region and their outcropping edges were thus given a northeast and southwest direction. The different degrees of hardness of these beds caused them to weather unevenly and subjected them to unequal degrees of aqueous erosion, so that broad valleys were cut out having the same direction as the beds themselves. To a greater or less extent the preglacial topography determined the direction of local movement of the great ice sheet and hence the direction of maximum ice gouging. The direction of the advance of the ice disposed the deposits of till, moraines, and boulders as we find them and gave to the county its present topography. This topography determined the direction of drainage, the boundaries of the series of lakes resulting from the melting of the ice and the direction of their shore lines. From the above mentioned remote cause an endless chain of causes and effects has been permanently impressed upon the county and all its inhabitants. But the forces by which the rock beds were originally disturbed represent a single link in this chain which reaches backward as well as forward. We have no means of knowing, at this remote day, what factors determined the direction of the operation of these potent forces. Could these but be identified and traced to their origin we should better understand the remark of some farseeing scholar, that if a single grain of sand on the seashore occupied the position of its neighbor, the history of the earth would have been different.

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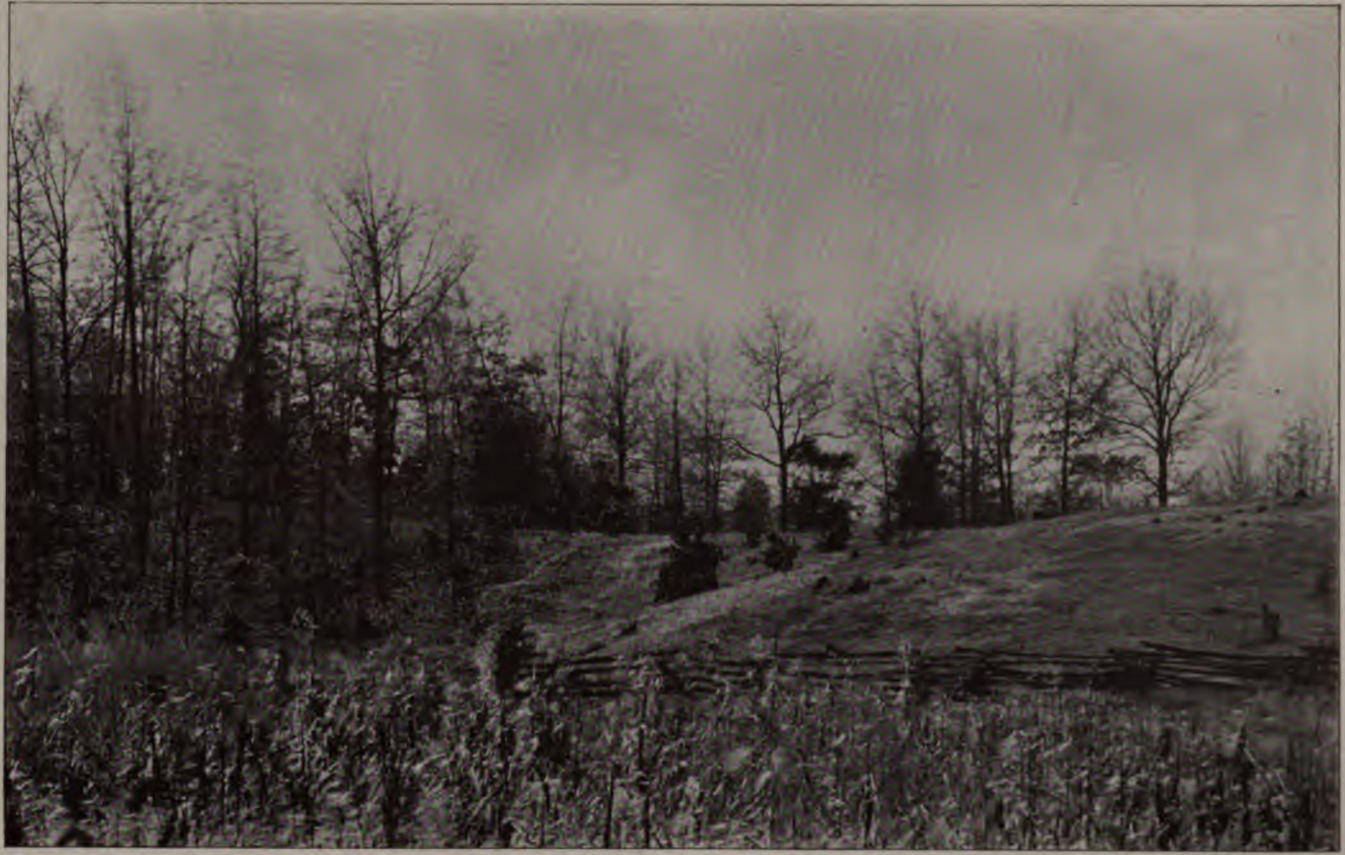

SAND RIDGE OF BEACH, WEST OF ERIE; SHOWING TYPICAL GROWTH OF OAK AND EVERGREENS.

CHAPTER VI.

THE GLACIAL EPOCH IN SOUTHEASTERN MICHIGAN.

A. Rock Surface Topography.

§ 1. Introduction.

No satisfactory knowledge of the peculiar topography, the nature and distribution of the soils of the county, can be had except through an understanding of the recent geological history of the region. Between the formation of the strata which have been described and the series of events about to be presented in this chapter, a very long period intervened. During this time the land had arisen from its long immersion in the sea and was probably not again submerged for any great length of time. It was acted upon by the meteorological and chemical agencies which operate to produce soil, the removal of which by erosion gradually brought the rock surface to a lower level. Broad, shallow valleys were cut across the county in a general northeasterly direction, which with their low, narrow divides characterize an aged river system. It is quite probable that tongues of ice moved along these valleys at times and somewhat modified their form, although their general direction does not coincide with that of the ice movement. The topography of the rock surface is shown by the contours given upon Plate I, each drawn to connect points where the rock surface is at equal elevation above mean sea level. The data for these contours were obtained by subtracting from the actual elevation of the surface, the thickness of the drift covering, so that there was a double chance of error in determining the result at any particular point. The contours must then be regarded only as approximately located, simply the best that could be done under the circumstances. The highest rock in the county extends northward through the western half of Whiteford township into Summerfield, ranging from 660 to 682 feet A. T., the latter elevation being reached at the head of Ottawa Lake. The maximum rock relief, within the limits of the county, is about two hundred feet. An inspection of the contours shows that there are three fairly well defined valleys within the limits of the county, which may conveniently be referred to by the names of the geological formations out of which they have been carved.

§ 2. Traverse valley.

This strikes northeastward across Milan township, approximately along the line of the Wabash railroad, having been cut out of the softer beds of the Traverse group. It is limited on the northwest by a narrow divide of harder rock (the Tully limestone?) which extends northeastward through sections 18, 7, 8, 9, 4, 3 and 2. This low ridge divides the Traverse valley from another which has been formed in the St. Clair shale and the two unite in the southeastern part of Washtenaw county. The stream which occupies the St. Clair was apparently tributary to that which flowed through the Traverse valley. This latter valley extended from the divide above located as far as Azalia and varied in breadth from about six miles in southwestern Milan to three to four in the northeastern part. Within the township the elevation of the central part drops from 610 to 549 feet, giving an average fall of about nine feet to the mile towards the northeast. The stream seems to have passed directly beneath the village of Milan about twenty-four feet below the present level of Lake Erie, or thirty-three feet lower than that of Lake Huron. The valley itself here was about sixty feet deep so far as we may judge from the present rock topography. Plate VI shows a section of this valley along the line of the Ann Arbor road. From well records collected in Wayne county this stream appears to have continued northeastward across Washtenaw, into Wayne and on towards Detroit, where its elevation is not far from 470 feet A. T., or about 100 feet below the level of Lake Erie.

§ 3. Dundee valley.

This is a broad, shallow trough, confined mostly to the richer and softer beds of the Dundee formation. It seems to head in the higher rocks in the northern part of Ida township, cutting across the upper Monroe beds and entering the Dundee at Raisinville. It then follows the strike of the softer beds into Wayne county, there cuts across the upper Dundee beds and opens into the main Traverse valley, showing that its stream was tributary. Within Monroe county the central part of the valley falls from 643 to 580 feet, or an average fall of four to five feet to the mile. At only one place does the stream channel itself appear to have been struck in well boring. In Sec. 18 of Exeter township, the rock averages 50 to 55 feet from the surface, but G. W. Palmer, (N. W. ¼, N. W. ¼) went 72.5 feet without reaching rock and ended in gravel. This stream probably left the county from Sec. 3 of Exeter at a somewhat higher level than did the Traverse to the west.

§ 4. Sylvania valley.

A narrow and still better defined valley followed the Sylvania sandstone throughout almost its entire course, owing to the uncompacted nature of this bed and the ease with which it could be eroded. The valley appears to have been formed by the union of two short ones, the first of which followed eastward the town line between Whiteford and Summerfield and the second came in from the northwest and joined the former in the southwestern part of Ida. The contours show how faithfully the strike of the bed was followed turning eastward with it in Ash and Berlin and cutting across Brownstown, of Wayne county. The breadth of the valley was roughly limited by the resisting dolomite beds on either side of the sandstone outcrop. In the southwestern part of Summerfield the valley has an elevation at its center of about 660 feet and drops 100 feet in reaching South Rockwood, an average of about three feet to the mile. The actual depth of the stream channel itself is unknown. One mile east of South Rockwood, in about the center of the valley (Sec. 10, T. 5 S., R. 10 E), Mr. J. M. Morrison has a well in which the depth to rock is eighty feet, while a short distance east, across the road, the rock is within twelve to fourteen feet of the surface. The lower section on Pl. VI gives a cross-section of this valley, at the outcrop of the bed marked "white sandstone." A small portion of the valley is also shown in the same bed at the left of the section along the Michigan Central road. The stream which occupied this valley emptied to the east, or southeast, very probably into the ancient "Erigan River," which is believed to have occupied the deeper portions of the bed of Lake Erie and the lower part of the Detroit River. The other preglacial or interglacial streams located appear to have continued northeastward and probably formed part of the ancient system which occupied the present site of Lake Huron.

§ 5. Erie trough.

Upon the southeastern side of the rock fold which has been previously described as "stony ridge," the elevation of which slopes from 663 feet A. T. to 575 feet A. T. at Lake Erie, the surface drops very rapidly towards the lake. The dip of the beds, upon the other hand, is towards the northwest, in the opposite direction. The steepest descent is in the western part of Erie township, where there is a drop of seventy feet within a distance of one and one-half miles. A flat shelf with a maximum breadth of two miles, then extends northeastward across the township, mostly west of the railroads and parallel with them. For the next mile to the southeast a further descent of forty feet occurs, bringing the actual elevation down to about 490 feet A. T., or 83 feet below the mean level of the lake. This rock topography is well shown at the right of each of the sections on Pl. VI, previously referred to. Northeastward this trough extends past Monroe and between here and Stony Point turns to the eastward and continues an unknown distance beneath the lake. Judging from the character of the beds affected, the shape and position of the trough, it seems probable that this is due to the gouging action of the great "Erie lobe" of ice.

B. The Ice Invasion.

§ 6. The early ice sheets.

The glacial history of the region covered by this report would be very unsatisfactory if read from this area alone. Data from widely distant localities are required in order to prepare even the most general account of this remarkable episode known as the Glacial Epoch. Two lines of evidence from within the county have been adduced to show that the land at one time stood at a higher altitude, at least, with reference to the present level of the great lakes. These evidences, it will be remembered, are the deep subterranean channels and the deeply buried river valleys. Supplemented with further evidence from other localities it is known that the land was considerably more elevated than at present and particularly so toward the north. This elevation combined with a possible change in the position of the earth with reference to the sun, the shifting of the great ocean currents or the withdrawal of a certain amount of carbon dioxide gas from the atmosphere, produced arctic conditions over the Dominion of Canada and northern United States.

A very heavy precipitation of snow over the region lying to the east and south of Hudson Bay, more falling each winter than could be melted away during the following summer, produced a great body of snow, which by its own weight and surface melting was compacted into ice, thousands of feet thick. It must have been just such a body of ice as now completely mantles Greenland and the Antarctic continent. On account of the peculiar quasi-plastic properties of ice and the elevation of the sheet, the ice moved slowly outward from the center as its production there continued.

As the ice moved to the south and west at a rate probably not greater than a quarter of a mile yearly, the frosty breath of this unwelcome visitor was finally felt about the northeastern boundary of our native state. Invading the lake region it slowly made its way southwestward, grinding and scouring the rocks, tearing loose and transporting great fragments, and annihilating every vestige of plant and animal life. The soil which had been accumulating for ages was scooped from the rocks and either pushed ahead of the ice or washed out from beneath by running water. We have no means of judging how long this great ice sheet tarried over this region, but it is known to have also crossed Ohio, Indiana, and Illinois, and to have entered Kentucky, before its progress was arrested. The ice front stood at its southern limit long enough to permit the accumulation of a great belt of debris, consisting of clay, sand, gravel, and boulders forming the line of hills known as the terminal moraine. During this stage of halt the backward melting of the ice just equaled the amount of its forward movement, so that the front was approximately stationary, and the materials undergoing transportation were indiscriminately heaped at its base. Climatic changes occurred and the rate of melting exceeded the forward movement of the ice itself, causing the ice front to slowly retreat northward. Practically nothing is known in this region of the details of this retreat; where or how often the ice front again became temporarily stationary and formed minor moraines, in what condition the drainage was left or where the water accumulated to form the great lakes of this stage. Beneath the ice sheet there had been formed the great "ground moraine," the rock grist of this great ice mill consisting typically of unstratified blue clay, charged with sand, pebbles and boulders, more or less bruised. The melting of the ice took place not only from the front but also from the upper surface and upon its complete disappearance the debris which it still contained was deposited over the surface of the clay. A forest growth of hardy trees sprang up and a dark soil bed was formed of varying thickness. Where conditions were favorable peat and marl beds and deposits of bog iron ore were formed. This first ice invasion was due to what has been termed by Leverett the Illinoian ice sheet, owing to its development in that state. A second sheet known as the Iowan is believed to have also crossed the state in the same general direction and to have restored arctic conditions. Data are not af hand for determining whether this second sheet was a simple extension of the first after a long interglacial period or whether it was developed anew as had been the first.

§ 7. The Wisconsin ice sheet.

In the same region east of Hudson Bay, over the Labrador peninsula a third great sheet of ice slowly mustered its strength and moved south and west. This was in consequence of a return to the unfavorable climatic conditions which had given rise to the first sheet. How long a time intervened we have no means of accurately judging, neither do we know how far northward the Iowan sheet had retreated. The time was sufficient to permit of the formations noted above, to allow the till to become leached of its soluble ingredients to a considerable depth, and oxidized into the reddish brown clay to which the term "ferretto" has been applied. The devastation wrought by the earlier sheets, from which our region had largely recovered, was repeated. The till covering of the bed rocks, with the superficial deposits, was in large part swept away, and the rock again heavily glaciated. The grooves and scratches produced by the Illinoian and Iowan sheets were in a large measure obliterated, and a new set substituted. From this further grinding of the rocks and the rearrangement of the materials of the former bed, a second sheet of till was formed. This differs from the earlier in being less compacted, less altered in color and of a generally fresher appearance. It is not impossible that some of the so called "hard-pan," which frequently occurs in the wells of the county, is to be referred to the deposits of the earlier ice sheets. But little trace could be obtained of a soil, or peat layer, separating the beds of till. Newspaper rumors, for several years back, have furnished some evidence of the occurrence of a layer of "coal" embedded in the drift of the southern part of Wayne county. In Sec. 34, S. E. ¼, S. W. ¼, of Huron township, Timothy Hanrahan dug a thirty foot well to the rock passing through a ten inch layer of what he called coal. Six miles south, in Ash township of Monroe county, Sec. 30, S. E. ¼, S. E. ¼, Mathias Waldecker put down a well, thirty-four feet to rock. Just over the rock he found mixed with clay, fragments of "coal" which would burn. In Bedford township of Monroe county, N. W. ¼, N. E. ¼, Sec. 2, John Van Wormer has a well ninety feet in depth in which the rock was struck at seventy-five feet. Six inch seams of a coaly substance were penetrated. The exact nature of this so called coal remains unknown but it is suggestive of compacted peat. The comparatively few wells in which this substance was reported, as well as of the dark soil bed which was probably formed on the surface of the earlier till, may be accounted for by considering the energy with which the last ice sheet operated in this region. The looser surface materials would be very liable to be destroyed, while the compact hardpan would more frequently remain undisturbed.

This Wisconsin ice sheet did not quite reach the Ohio River, so that between its terminal moraine and that of the Illinoian the oldest bed of till was undisturbed by ice agency. Its final retreat was marked by periods of halt and short advance, of a more or less rhythmic character as pointed out by Taylor.*

Between Cincinnati and Mackinac this investigator counts fifteen terminal moraines produced by this behavior of the ice sheet. The position and form of these moraines, when traced in either direction, gives the exact position and form of the ice front at these successive stages. Great streams of water, due to the friction of the ice upon its bed and the surface melting, made their way through and beneath the ice. These streams rounded and assorted the smaller rock fragments within reach and produced great quantities of sand and gravel. Some of this material was deposited in the tunnels and cavities about the margin of the ice, forming loosely stratified knolls and ridges known as kames and eskers. Much of it was washed out from beneath the ice and spread over the till froming a gravel plain upon the opposite side of the moraine from the ice. Where this material was brought to the ice front by a single stream, whose velocity was checked as soon as it emerged from the ice, a fan-shaped, delta-like deposit was formed. None of these glacial deposits occur within the limits of Monroe county, but good examples of all of them may be found in Lenawee and Washtenaw counties, adjoining.

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*Moraines of Recession and their significance in Glacial Theory. Journ. of Geol., Vol. 5, No. 5, 1897, p. 421.

§ 8. **Rock scorings.**

As early as 1839 Bela Hubbard published the bearings of well defined scratches which he observed upon the rock surface at Point aux Peaux and at Brest.* These were due he then thought to "the attrition of hard bodies moving in a strong current." At the former place he determined their direction to be ("N. 60° E.") S. 60° W., and at Brest ("N. 50° E.") S. 50° W., and N. 65° W. Some twenty years later Winchell found the rock at Stony Point well exposed and "covered with a set of striæ running in perfectly parallel lines N. 60° W."† Crossing this set he found two parallel grooves, bearing N. 60° E. to S. 60° W., which were 4 ft. 6½ inches apart, 1¾ inches deep, 2 inches wide and 25 feet long, much resembling wagon tracks in a yielding substance. The Ohio Geological Survey has at times published similar data in regard to the scorings observed in northern Ohio and the islands in the western part of Lake Erie. The first of these were collected by Gilbert and threw light upon the general direction of ice movement in southeastern Michigan.‡

In Lucas county, which adjoins Monroe county upon the south, the observations were made at four points. The mean of five observations at Sylvania gave S. 50° W.; near Holland one reading gave S. 55° W.; four observations at Monclova averaged S. 62° W. and one reading at Whitehouse, the farthest south, equaled S. 50° W. Upon West Sister Island the general direction is S. 80° W., with a comparatively weak set crossing them due south. The effect of the ice upon the limestone where chert nodules protrude is to produce the "knob and trail" phenomenon. The hard rock protects a ridge of limestone upon the lee side, while that in front of the nodule and along the sides is planed off and in certain cases grooved. This is convincing evidence of the direction of the ice movement, and as observed upon this island and at Monclova, proved that the movement was westward rather than eastward. Upon South Bass Island the striæ run S. 80° W., with a second series S. 15° W. At Sandusky the direction is S. 80° W., at [illegible] S. 65° W., and at Genoa S. 65° W. Vol. VI of the same Survey, in 1888, page 756, devotes a paragraph to the glacial markings at Kelley's Island and the [illegible] deflection of the ice by prominent rocks. The general direction of the striæ is given as S. 75° W., which striæ upon the

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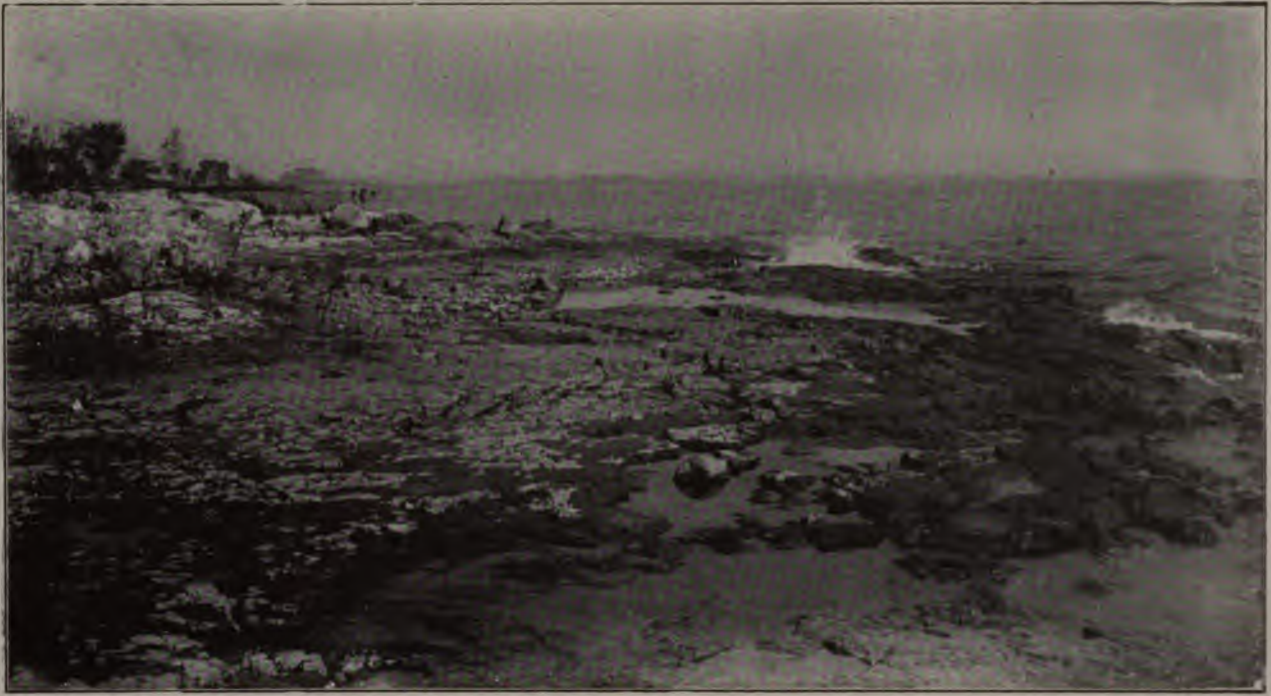
* [illegible] Report of the State [illegible]

† [illegible]

‡ [illegible]



ICE POLISHED AND BRECCIATED OUTCROPS AT STONY POINT, LOOKING NORTHEAST.

eastern end of the island are found to be crossed by a later set extending S. 76° to 80° W.

In Wayne county, to the north of Monroe, an examination was made of the glacial striæ about the Sibley quarry. At the time of the first examination a few were found bearing S. 64° W. and these seemed to be the oldest. A recent inspection of the rock now stripped failed to show any of this series. Upon three sides of the quarry, and particularly the eastern, the rocks were heavily grooved by an ice sheet which moved about S. 28° W. Some of these grooves are from one to two feet deep, but mostly only a few inches. It is only in these grooves that these striæ are preserved. Outside they have been replaced by a newer set, the mean of 21 observations giving a bearing of N. 27° W. and a range of from N. 19° to 38° W. The evidence that the sheet moved northwestward, instead of southeastward as has been previously reported and believed, is very conclusively shown at the Sibley quarry. "Chatter marks" occur with their convexities directed toward the southeast, "disruptive gouges" are formed with their concavities in the same direction. Where the ice crossed a groove previously formed, it was not yielding enough to settle into it completely, so that the eastern side of the groove was but slightly striated while the opposite side was more or less affected, being rounded and irregularly scratched. Projecting knobs of limestone show the most bruising upon the eastern, or southeastern faces and but little upon the opposite, or lee faces. But the most conclusive evidence is furnished by one bed of limestone which contains irregular masses of chert. This bed shows the trails of limestone, extending northwestward from these harder masses, with a very decided frontal and two lateral grooves, surrounding each nodule. These phenomena have all been described and figured by Chamberlain in his paper on "The Rock-Scorings of the Great Ice Invasions," published in 1888.*

Within the limits of Monroe county there are a number of places where the glacial striæ may be observed and a few localities where they may be very satisfactorily studied. Although many irregular and more or less distinct striæ may be observed, still, so far as direction is concerned, the principal ones seem to fall into three groups which may be correlated with those observed at Trenton. These are not all equally well represented at each locality and it is not always true that the newer set predominates over the older, the latter at times having been protected apparently by clay from the work of the later sheet. The principal information relating to these Monroe county scorings, as collected by the writer, is given in the accompanying table and shown graphically upon Plate VII by means of arrows. The striæ observed by Hubbard and Winchell at Point aux Peaux, Stony Point and Brest running S. 50-60° W. "N. 50-60 E." correspond in direction with the oldest observed at Trenton, S. 64° W., and are believed to have been formed at the same time. The next oldest set has a more southerly course and was formed during an energetic stage of the ice sheet. The heaviest grooving was observed at Trenton where the direction of movement was S. 28° W. In the heavy grooves on Kelley's Island the direction of movement was S. 23° W., as given above by Orton, so that these grooves and striæ are apparently to be correlated. Between these points at numerous places striæ are found which should be referred to this same stage of glaciation. Upon the islands at the western end of Lake Erie, in the eastern part of Monroe county and at Trenton, the freshest striæ have a westerly course ranging from a few degrees south of west to 52 to 71° north of west. These were produced by the central and northern portions of the Erie lobe of the Wisconsin sheet and indicate simply that the ice moved out at right angles to its front wall, as located by the moraines. It would be natural to refer the two earlier sets of striæ to the Illinoian and Iowan sheets respectively but we have no warrant for so doing. It is true that when the next oldest set was formed the ice was much more vigorous in its action but this is only what would be expected of the Wisconsin sheet when it was first advancing across the region, or had attained its extreme southern limits. In the last stages of its retreat it was able simply to smooth, polish and striate the rock surface but not to form heavy grooves. The direction of movement of the same sheet would also be expected to differ greatly over the same area at different stages of the ice development. Quite generally, however, there is a noticeable difference in the relative degree of freshness of the striæ, the older set having preceptibly aged. In the case of the newer series there is sometimes a question in one's mind as to whether a given short scratch was produced by the ice, or by the tool with which the stripping of clay was removed. The doubt rarely arises with regard to the older set, its striæ being duller, less sharply cut and slightly weathered. In some instances, however, it seems impossible to detect such differences between the older and newer series, where they both presumably have been well protected by clay. Near Brest there is a knob of dolomite, which appears at the side of the road just south of Stony Creek. The bearings of delicate scratches were taken here sixty years ago and still appear fresh in the case of the later series. Upon the lee side of the knob the older set was protected from the last ice sheet and although plainly grooved the striæ are well nigh obliterated. This would seem to indicate that a considerable period of time elapsed between the making of the two sets, during which time the ordinary destructive agencies were at work upon the oldest. In the western part of the county the correlation of the striæ is rendered uncertain on account of the relative age which it seems necessary to assign to the two series observed at several localities. The rock in the bed of the

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*Seventh Annual Rep. of the Director U. S. Geol. Sur., pp. 147-248.

TABLE VII.—GLACIAL STRIÆ IN MONROE COUNTY.

Locality.	Relative age.	Relative abundance.	True bearings of striæ.	Mean.
Sissung quarry	Newer	Most	N. 58° W., N. 55° W., N. 56° W., N. 59° W., N. 59° W.	N. 57° W.
	Older	Fewest	S. 37° W., S. 41.5° W., S. 31.5° W	S. 37° W.
Point aux Peaux	Newer	Fewest	Not present or quite obliterated	
	Older	Most	S. 20° W., S. 17° W., S. 19.5° W., S. 28.5° W., S. 18.5° W.	S. 21° W.
Stony Point	Newer	Fewest	N. 51° W., N. 44° W., N. 51° W., N. 79° W., N. 54° W., N. 46° W.	N. 54° W.
	Older	Most	S. 8° W., S. 6° W., S. 9° W., S. 8° W., S. 8° W., S. 20° W.	S. 10° W.
Brest	Newer	Most	N. 57° W., N. 58° W., N. 59° W., N. 53.5° W., N. 59° W.	N. 57° W.
	Older	Fewest	S. 10° W., S. 7° W., S. 8° W., S. 11° W., S. 9° W.	S. 9° W.
Monroe stone quarry	Newer	Most	N. 54° W., N. 52° W., N. 46° W., N. 42.5° W., N. 47.5° W	N. 48° W.
	Older	Fewest	S. 12 5° W., S. 10.5° W., S. 14.5° W., S. 10° W., S. 13.5° W	S. 12° W.
Plum Creek	Newer	Most	N. 62° W., N. 60° W., N 61° W.	N. 61° W.
	Older	Fewest	S. 7° W., S. 5° W., S. 6 W	S. 6° W.
Head of Ottawa Lake	Newer	Fewest	S. 22° W., S. 22° W., S. 19° W.	S. 21° W.
	Older	Most	S. 81° W., S. 91° W., S. 78° W., S. 107° W	S. 89° W.
Ottawa Lake quarries	Newer	Fewest	S. 24.5° W., S. 25.5° W	S. 25° W.
	Older	Most	S. 70° W., S. 70° W., S. 69° W., S. 70° W.	S. 70° W.
Macon river bed	Newer	Most	S. 38° W., S. 39.5° W., S. 38° W., S. 38° W., S. 35° W.	S. 38° W.
	Older	Fewest	N. 73.5° W., N. 76° W., N. 73° W	N. 74° W.
Woolmith quarry			S. 41° W., S. 36° W., S. 26° W., S. 26° W., S. 47° W	S. 35° W.
Inlet Ottawa Lake, Sec. 19			S. 65 5° W	S. 65° W.
Halfway Creek, Sec. 35			S. 56° W., S. 59° W., S. 55° W., S. 55° W.	S. 56° W.

Macon and the Raisin at its mouth is heavily glaciated. The main direction is S. 38° W., but a few heavy scratches, apparently older, run N. 74° W. From their direction alone there should be no hesitation in referring the latter to the newer series observed to the east. At the Ottawa Lake quarries the older set runs S. 70° W. and the newer S. 25° W., while one-half mile south at the limited rock exposure at the head of the lake, the older set lies in a shallow groove, with its striæ S. 89° W. and the newer set S. 21° W. These striæ could be very satisfactorily correlated, with those in the eastern part of the county providing their age was reversed. It would seem that those having the westerly course must correspond with those made by the Erie lobe, in which case it is a problem to know how to dispose of the later series ranging from S. 19° to 39.5° W. Further observations might furnish a satisfactory explanation, but as it now appears it seems necessary to assume a local ice movement subsequent to that described as the latest in the eastern part of the county.

C. Lacustrine Stages.

§ 9. Introduction.

For some reason, possibly on account of the great weight of the ice sheet, a marked subsidence of the earth's crust occurred over the region thus covered. This change, combined with others affecting the position of the earth with reference to the sun, or perhaps an increase in the amount of carbon dioxide in the atmosphere, restored the equable climate which this region had enjoyed previous to the great catastrophe and led to the disappearance of the ice sheet. The melting of such a body of ice, together with the normal precipitation, would furnish enormous quantities of water for the greatly disturbed river systems to take care of. The sub-glacial streams, contracted by narrow walls, would leave the ice with great velocity and carrying much sediment. Upon spreading out in the depressed and partly filled river channels, leading from the ice front, the velocity would be greatly checked and much sand and gravel deposited. This epoch was short when compared with the preceding and corresponds more or less with the Champlain epoch of the east. A reëlevation of the land followed the disappearance of the ice sheet, the streams were given greater fall, and hence greater velocity, and began clearing out their obstructed channels, forming a series of terraces at successive levels. While this was the course of events in the east a very different program was carried out in southeastern Michigan and northwestern Ohio.

§ 10. Lake Maumee.

(a). Van Wert stage. As the ice began its retreat northeastward down the Maumee valley from Ft. Wayne, Indiana, lower and lower land was successively exposed. This depression filled with water as the ice receded, and a lake of correspondingly greater proportions was formed, to which the name of Maumee was appropriately given by Dryer, in 1888.*

When the apex of the lobe had reached Defiance, Ohio, the ice front halted, or made a slight advance, and a moraine formed to mark this episode in its history. This moraine may be followed southeastward through Findlay from Defiance and northeastward through Adrian, being known as the Defiance moraine. It consists of one or more rows of rather subdued hills, passing to the west of Ypsilanti, near Northville to Rochester, where it turns northward into Lapeer county. It marks the approximate position of the ice front which was acting as a great retaining wall to prevent the water now spreading over the upper part of the Maumee valley from flowing in the natural direction of drainage. Where the waves of this lake impinged upon the land a gravel and sand beach was formed at an elevation, in the region under study, of about 220 feet above Lake Erie level, or 793 feet above tide, thus marking the approximate elevation of the surface of the lake itself. Some half dozen different names have been assigned to this beach in Ohio and Michigan, which it would cause confusion even to mention. The, latest to be suggested is Maumee, as being the simplest but if two stages of Lake Maumee are to be recognized, there is no reason why one beach should be so named rather than the other. Since this same term has also been applied to the Leipsic Beach, and since they both are frequently referred to as the upper and lower Maumee, it seems best to the writer to retain one of the original names, the one most frequently used and to reserve Maumee for general use, when one or both beaches are to be designated.

According to Leverett who has now followed this beach more continuously than any other investigator, its normal height varies from five to ten feet and its breadth from ten to twenty rods. It is known to extend from Findlay, westward to Ft. Wayne and thence northeastward to Adrian, where it is supposed to have temporarily met the retaining ice wall. As pointed out by Taylor the lake was in the form of an arrow-head, with the point at Fort Wayne and a barb each at Findlay and Adrian. It is to the latter author that we are especially indebted for the facts pertaining to the lacustrine geology of eastern Michigan.* The distance across the barbs is about 75 miles, and about 40 miles from Ft. Wayne back to the ice wall at Defiance, where the lake is estimated to have been 60 feet deep. The lake drained southwestward from Ft. Wayne, through a now abandoned channel and entered the Wabash River near Huntington.

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*Sixteenth Annual Report of State Geologist of Indiana, Geology of Allen County, pp. 107 to 126.

When the ice again began its retreat it withdrew from the Defiance moraine and the lake (still at the same level), filled in between this moraine and the ice wall, forming a long narrow arm, extending farther and farther to the northeast. In consequence, the Maumee Beach was continued beyond Adrian and was formed upon the inner (iceward) side of the Defiance moraine for many miles, finally reaching Imlay in Lapeer county. Thus far we are simply dealing with the gradually enlarging, first stage of Lake Maumee.

During this stage of the lake the ice front is believed to have made two periods of halt and advance, as marked in this region by the Defiance and the Cleveland moraines. The moraine designated by Taylor as the Toledo was supposed by him to pass southwestward across Monroe county around Toledo and to connect with Leverett's Cleveland moraine. This moraine could not be recognized by the writer in Wayne and Monroe counties, as a surface feature, although there is suggestive aggregation of boulders and cobbles in the eastern part of Whiteford township, which may be in the line of such a moraine. Possibly because of its waterlaid character it may have been so completely obliterated as to be easily overlooked. There is some little evidence that it strikes southeastward from Birmingham toward Detroit, where it may pass under the Detroit moraine. If this should prove to be the case it would be necessary to conclude that the ice receded from the Toledo moraine, halted and in its advance near Detroit had pushed beyond the position which it had occupied when the Toledo was laid down. Between Wyandotte and Trenton there swings in from the river a series of gentle till swells, carrying boulders and cobbles, which are believed to constitute the western edge of the Detroit moraine. Similar ridges occur on Grosse Isle with a direction a little south of west. West and southwest of Trenton these low ridges are well defined and are charged with small rock fragments. Their direction in Monguagon township is southward turning to the southsoutheast as they pass in to Brownstown and then again due south as they approach the Huron River. From the Huron southward the ridges have disappeared but there is an aggregation of cobbles and boulders to the east and southeast of Newport which proves that the Detroit moraine really extends across Berlin and the eastern part of Frenchtown to Stony Point where it enters the lake. Southwest of Brest for a mile or more there is a mere suggestion of morainic topography, the swells running east and west.

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*Correlation of Erie-Huron Beaches with Outlets and Moraines in southeastern Michigan; Bull. Geol. Soc. of America, Vol. 8, page 31, 1897. The Great Ice-dams of Lakes Maumee, Whittlesey and Warren; Amer. Geol., Vol. XXIV, 1899, page 6; A short History of the Great Lakes; Inland Educator, Vol. II, 1896; pp. 101, 138, 216. The correlation of the Toledo moraine above suggested Mr. Taylor now considers uncertain. The subject is now (summer of 1900) under investigation by Messrs. Leverett and Taylor. Prof. Sherzer's proof has been revised by them so as to bring his references to them in harmony with their present information. L

(b). Leipsic stage. When the great tongue of ice had withdrawn from beyond the present site of Imlay, ground was uncovered which was at a lower level than that of the lake itself and an outlet, northwest to the Flint River was opened. This was neither large enough, nor low enough to entirely take care of the surplus water that was rapidly supplied and the Ft. Wayne outlet also continued to serve. The level of the lake fell ten feet or more in consequence of the opening of the Imlay outlet and a new beach, known as the Leipsic was formed entirely around the margin of the now lowered Lake Maumee. During the greater part of the first stage described Monroe county was probably covered with the ice, but during the latter part of this stage and practically the whole of the second, the county was under water, about two hundred feet of which covered the site of the city of Monroe.

§ 11. Lake Whittlesey.

Beginning again its slow retreat the ice front receded in the direction of Port Huron and northeastward down the bed of Lake Erie, dividing into respectively the Huron and Erie lobes. The former withdrew as far as Port Huron and formed the Port Huron moraine, which extends from near this city, northwestward between Black River and the present Lake Huron shore, meeting at Ubly the contemporaneous moraine formed by a lobe of ice which occupied the Saginaw valley. The ice thus uncovered lower land lying between Ubly and Tyre, in the southern part of Huron county, a new outlet was formed leading southwest into the Cass River and the level of the glacial lake fell about forty feet., forming the lake to which Taylor has given the name Whittlesey. The new beach formed by this body of water stands at an elevation of 743 feet, in southeastern Michigan, or 170 feet above Lake Erie level, and is now generally known as the Belmore. It is a gravel and sand ridge from twelve to fifteen feet high and several hundred feet broad, the best defined of the entire series of beaches in this part of the state. It lies to the east of the Van Wert and Leipsic beaches and approximately parallel with them, its distance depending upon the topography of the county, but averaging from two to four miles. It enters the state from Ohio, about twelve miles west of the southeastern corner of Lenawee county, passes northward to Lenawee Junction and then turns to the northeast, passing through Ridgeway, York, Stony Creek, Plymouth etc., to the outlet noted. The "ridge," as it is called locally, cuts the extreme northwestern corner of Sec. 6, of Milan, the diagonal road following its crest for many miles between Pontiac and Adrian. A good section of the upper part of the beach is shown in a gravel pit just west of where it is cut by the Ann Arbor road, north of Milan. The section here shows at one point; 5½ inches of brown, gravelly, unstratified clay soil; 30 inches of light brown, roughly stratified clay sub-soil, becoming a deep rusty red. The clay passes into a coarse sand and this into fine gravel, with some pebbles as large as hens' eggs. This gravel is well stratified; 6 inches of perfectly stratified, fine sand; 10 inches of grit, obliquely laminated; 1 inch layer of fine gray sand mixed with some clay; 48 inches of stratified gravel, with the strata dipping towards the lake side. The gravel is very fine towards the upper part of the bed, becomes gradually coarser and then finer. One layer is thoroughly washed from fine sediment and is loose and open, the remainder of the bed has more or less sand.

Total thickness of section equals 8 feet 4½ inches.

The farmers living upon the beach very generally report that the gravel layers extend to a depth of twelve to fifteen feet and that water is readily secured from the lower beds.

Owing to the inaccessibility of the early geological reports of the state, credit is not usually given Bela Hubbard for his observations upon the surface geology of the region and for his sagacious interpretations of the same. The Belmore Beach he had followed for many miles and in 1840 he described it under the name

"Ancient lake ridge,* as a continuous gravelly ridge having a course parallel with the present shore of Lake Erie and the Detroit river. He observed its structure and the sudden change which it marks in topography, the surface to the east being low and flat, while that to the west is more elevated and rolling. He recognized the differences also in the character of the soil and of the timber upon opposite sides of the beach. The elevation he gave erroneously as 107 to 108 feet above Lake Erie but he clearly saw that it marked the level of a great sheet of water. The difficulties in the way of such an interpretation were stated to be in accounting for such a supply of water and in finding barriers capable of confining it. The possibility of an Appalachian uplift across the St. Lawrence and the Highlands across the Hudson, serving as barriers is suggested, in which case

> "a single communication only would then exist with the ocean, viz.: through the valley of the Mississippi. * * * That the lakes once discharged their waters in this direction, such additional evidence is furnished by the appearance of the country, that in this our argument but serves to add confirmation to the general opinion."

The existence of a barrier at Mackinac, cutting off Lakes Michigan and Superior, with the closing of the outlet to the Mississippi would cause the level of the water to rise until it would break through the Mohawk and Hudson and finally through the St. Lawrence. (p. 106.) From fossils found in the Saginaw and Niagara valley deposits he concluded that the water was *fresh*, although he suggests the probability of a subsidence to ocean level, with barriers cutting off the influx of the sea and "disproportionate elevations." In the report above referred to, a topographic map of Wayne county is published, the work of S. W. Higgins, upon which the Belmore Beach is located. Instead of entering Livonia township at the northwestern corner of Sec. 18 and cutting diagonally across Secs. 7 and 5 the beach is represented as following the town line north between Livonia and Plymouth. This error arose from the fact that the Maumee Beach leaves Wayne county on this town line and the two beaches were, in consequence, confused. A glance at the drainage of the region should have made the error apparent. Hubbard followed the beach across Oakland and Macomb counties, into St. Clair, and discovered a number of other inferior ridges between this and the Lake Huron shore. On his map of Lenawee county issued by the Geological Survey it is traced from a quarter of a mile south of the northeast corner to Sec. 19, Palmyra township. "This ridge is from 10 to 20 feet high, the former boundary of the lake shore composed of sand and gravel." The strip of land lying between the Belmore and Maumee Beaches, including the extreme northwestern corner of Monroe county, was uncovered by water during the existence of Lake Whittlesey and gives evidence of long continued surface erosion. This feature, combined with the great strength of the beach, leads to the conclusion that this lake persisted for a relatively long time.

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*H. R., No. 8, p. 102; H. D., No. 27, p. 278; S. D., No. 7, p. 138.

§ 12. Arkona beach.

The recession of the ice front from the Port Huron moraine opened an outlet, or series of "spillways" from fifty to sixty feet lower than the level of Lake Whittlesey. The position of these outlets was located by Taylor across the "thumb" north of Ubly rather than around it to the north, and correlated hypothetically with this beach, so that the general direction of drainage of the former lake was continued. The great difference in level between this body of water and that of Lake Whittlesey, with the consequent changes in form and drainage, justify its separation from the latter lake. The fact that it was not confluent with Lake Saginaw seems a ground for not regarding it as simply an early stage of Lake Warren. See Part II of this volume, upon Huron county.

It seems probable that this stage in the lake history continued only while the ice was retreating from the Arkona outlets to the position it occupied when Lake Warren was formed. This was of relatively short duration and the beach, so far as it has been followed in Michigan, is of a weak, tortuous character. In Wayne, Monroe and Lenawee counties it is a rather wide, but flat sand ridge, from two to four feet above the general level. Broad areas of pebbly sand are occasionally associated with the faintly developed swell of sand, and cuts into it at the roadside show fine gravel layers to a depth of from two to three feet. From the beach lakeward there is a gradual surface slope apparent, by which the Arkona may be recognized aside from the materials of which it is composed and its surface elevation. Aside from its weak development the beach is peculiar in the fact that it does not take a direct course. It seems to have simply followed its surface contour, its course being determined very largely by the topography instead of determining the topography. An inspection of Plate VII shows the beach entering Monroe county from Washtenaw, about 1¾ miles east of the village of Milan. It passes southwestward across Milan and Dundee townships, following closely the 690 foot contour, but lying to the west. Leaving the county in Sec. 6 of Summerfield the topography causes it to make a curve to the west in Lenawee county, crossing the Raisin and reëntering Summerfield township south of the river in Sec. 18. It then passes eastward to the south of the river road and turns northeast toward Petersburg. Southward for nearly three miles its sand is mingled with that of the next lower, or Forest Beach. In Sec. 21, it swings westward, leaves the county again and makes another but larger curve to the west owing to the relatively depressed and very flat character of the surface in southern Summerfield and northern Whiteford townships and the adjoining portions of Lenawee county. From Dundee township, through Summerfield the sand has been heaped into mounds and ridges through the agency of eastern winds. According to Spencer the beach extends westward to Blissfield where it has the same duny character and an elevation of 694 feet. It then turns eastward and makes a regular curve in the southwestern corner of Whiteford, west of the railroad. It here consists of a rather well defined swell of gravelly sand, the dunes seen to the west and north having disappeared. The beach turns westward, and enters Ohio from the southeastern corner of Lenawee county. Through this region it is separated from the sand of the Forest by a belt of heavy clay. In his map of the raised beaches north of the Maumee River* Gilbert did not recognize this as a separate beach. It enters Ohio between his third and fourth beaches about five miles east of the northwest corner of Lucas county. It is not improbable that to the southwest it may be incorporated in the broad belt of sand mapped as the Fourth Beach. Spencer gave the elevation of the Arkona at Dentons, on the Michigan Central in Wayne county, the same as at Blissfield, 694 feet, and this appears to be approximately correct. It would seem as though a very few years would suffice to construct a beach of such strength. In places a miniature ridge was observed, running parallel with the main one, but one-fourth of a mile distant, on the lakeward side, and from two to three feet lower. While this stage of the series of ice-dammed lakes persisted that portion of these townships lying to the west of the beach was above water. Over Monroe City the water stood from 100 to 105 feet deep.

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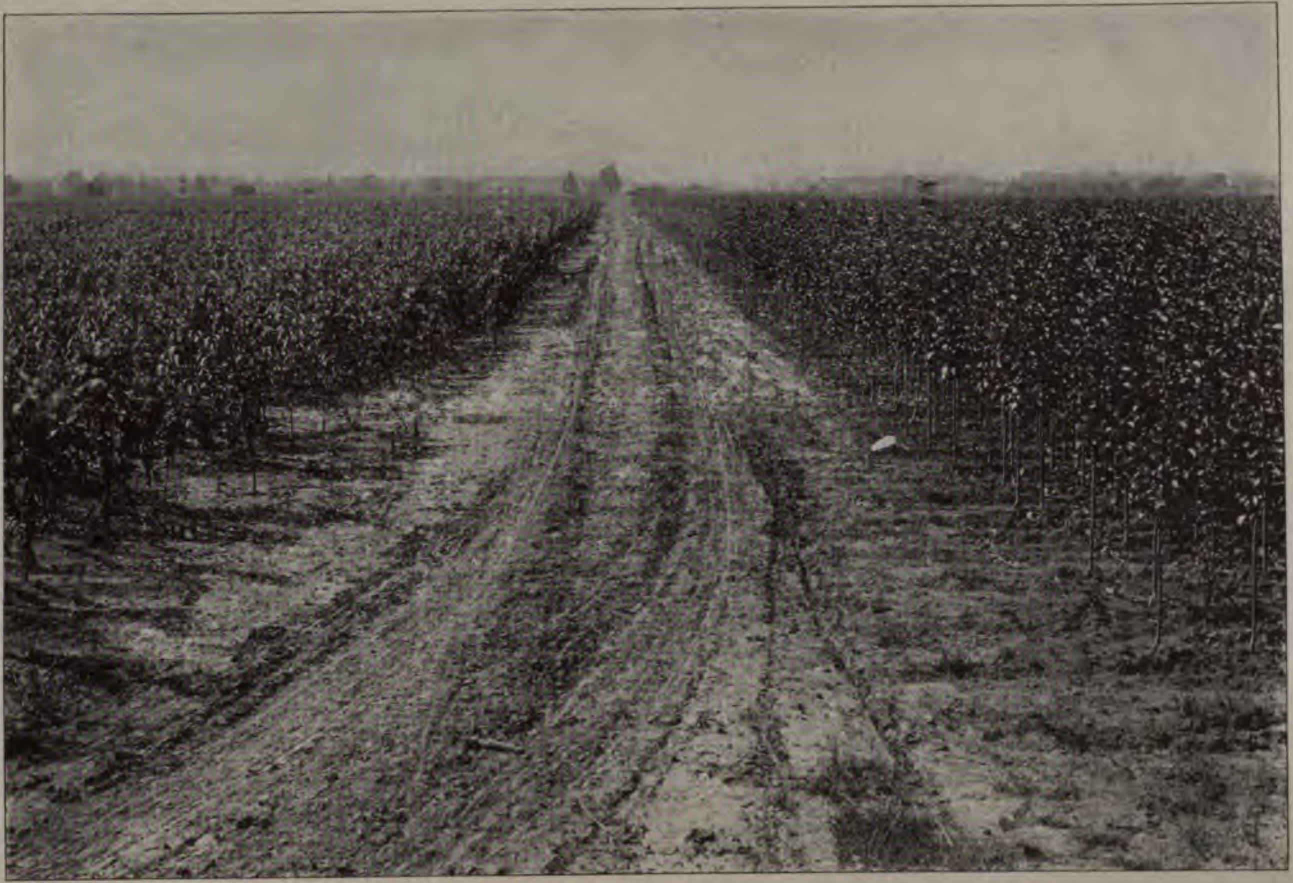
*Geol. Survey of Ohio, Vol. I, 1873.

§ 13. Lake Warren.

(a). Forest stage. From near Sylvania, in Ohio, there enters Monroe county a broad belt of heavy yellow sand which was termed by Gilbert, in 1873, his beach No. 4. This he regarded as representing a gradual subsidence of the glacial water from 90 to 60 feet. In Bedford township this belt divides into two, as shown upon Plate VII, the main part of which passes northward through Ida, Dundee and London townships, lying between the contours of 90 to 80 feet above Erie level. This strip of sand has been called the Forest Beach by Spencer and it outlines a great sheet of water to which has been given the name Lake Warren. So far as seen in Monroe county there is no well defined ridge, as in the previous cases, but simply a belt varying in width from four to seven miles, over which the loose sand has been heaped by the wind into mounds and ridges. Some of these ridges continue for several miles and attain a height of twenty to twenty-five feet. In places heavy double ridges occur, parallel with the shore line. This Forest Beach cuts the southeastern corner of Washtenaw county, passes across Wayne county, intersecting the Michigan Central road at Wayne station, and continues northeastward by Port Huron into the "thumb." The elevation of the rail at Wayne is 87 feet above Erie level and this marks approximately the center of the belt. In passing northeastward from Dentons to Goodells, west of Port Huron, the Arkona rises seven feet owing to a differential uplift. In this vicinity the Forest has an elevation of 92 feet above Erie (665 above tide, according to Spencer) and if we assume the same differential movement the Forest in Wayne, Washtenaw and Monroe counties would have an elevation of 85 feet above Erie, or 658 feet above tide.

As the ice front retreated from the Port Huron moraine, beyond the place at which the Arkona outlet had been opened, it made its next halt and slight readvance along a line extending from the point of the "thumb," northwestward through Harrisville and Alcona, in a curve to Petoskey, depositing the Alcona moraine. As the ice moved down the northern slope of the "thumb" a series of temporary outlets were opened into the Saginaw valley, and finally the waters in front of it thereafter known as Lake Warren became confluent with those of Lake Saginaw. (See Part II of this vol-



MONROE NURSERY. TYPICAL OLD LAKE BOTTOM. AND WAVE-WASHED FLAT.

ume, Geology of Huron county, Fig. 4, Plate VIII.) According to the observations of Gilbert, Taylor and Lane the Forest Beach in this northern region is characteristically double, showing two well defined gravel and sand ridges, with a difference in level of eight to fifteen feet. In the southeastern part of the state it is very probable that similar beach ridges were also formed, which were later covered by shifting sand and completely obscured. The shape of Lake Warren during this stage was such that with a prevailing northeast wind the waves would strike with greater force upon the shelving shore of southeastern Michigan, than upon the "thumb." A greater amount of sand would thus be tossed up by the waves and carried inland. The common outlet of the Saginaw and Warren lakes is known to have been through the Pewamo channel, extending from Maple Rapids, by Pewamo, Muir, and Ionia to the Grand River. This channel is fifty miles long and from three-fourths to a mile wide, with a fall to the southwest of not more than a foot to the mile. Through this outlet the waters of all the glacial lakes described, except Lake Maumee in its first stage, drained to Lake Chicago, thence through the Chicago outlet and on to the Mississippi.

(b). Grassmere stage. A second beach, not hitherto recognized in this region, branches from the broad belt of sand which enters Bedford township from Ohio, and passes northeastward through Erie, La Salle, Monroe, Frenchtown and Ash townships (See Plate VII). As seen in Monroe and Wayne counties it consists of a belt of yellow sand, from two to three miles in width, covered with heavy ridges and knolls between the contours of 610 to 620 feet above tide (37 to 47 feet above Lake Erie level). It is the reduced counter part of the Forest Beach and was made by Lake Warren after it had suffered a drop in its level of about 43 feet, caused by the clearing away of some obstruction in its outlet. That the drop was not sudden is evidenced by the fact that this beach is connected in places with the Forest by light coverings of sand and but little heavy surface clay separates the two. The drop from this stage of Lake Warren to the present Lake Erie level, a distance of about 42 feet, was apparently much more rapid. Plate XI gives a view of one of the heavy ridges of sand seen just west of Erie.

These are abundant and characteristic from the Ohio line to Dearborn, as far as the writer has followed the beach continuously. According to the Michigan Central profile the approximate elevation of the central portion of the belt is 615 feet A. T. and at Carleton about the same. In his survey of Huron county (See Part II of this volume) A. C. Lane has identified a series of beaches which are at the right elevation, below the Forest, to include this one. To this series he has given the name Grassmere. The subjoined table shows at a glance the main facts pertaining to the glacial lakes of southeastern Michigan. The glacial history outlined thus briefly in this chapter furnishes the key to an understanding of the physical features of Monroe county. It accounts for some peculiarities of the rock surface, the nature and distribution of the materials which cover the bed rock, and the surface topography with attendant drainage. All parts of the surface were successively subjected to wave action which cut down prominences and filled in depressions. A layer of sediment was spread over the entire county, thin to the west, thicker towards the east and southeast. This consists of a dark colored, finely divided clay, generally free from pebbles. A good impression of the effect of this action upon the topography is shown in Plate XIII. Much of this was removed by wave action as the water receded and much of it has since been removed by surface erosion, so that in many portions of the county the pebbly till reaches the surface, or is covered by only a few inches of vegetable mould. Over these regions the surface boulders are only slightly imbedded, while in the eastern and southeastern portions of the county the deposit is thicker and the boulders generally covered. The thickness observed in a number of places varies from two to three feet, and the maximum in Erie township is undoubtedly much greater. From the crest of "stony ridge" this deposit has been removed very largely through erosive agencies. The source of this clay was the till, from which the sand and pebbles were removed by waves and thrown upon the beach, while the finer clay particles were held in suspension, carried lakeward and deposited in the deeper water. The clay used in the Monroe brickyard must have sand added to it before it is suitable for brick and tile. In front of the Arkona beach in the southwestern part of Dundee township there are patches of wave washed till from which the waves removed the sand and fine clay but were not strong enough to disturb the pebbles. In consequence the soil is full of small pebbles and the beach is very largely composed of sand.

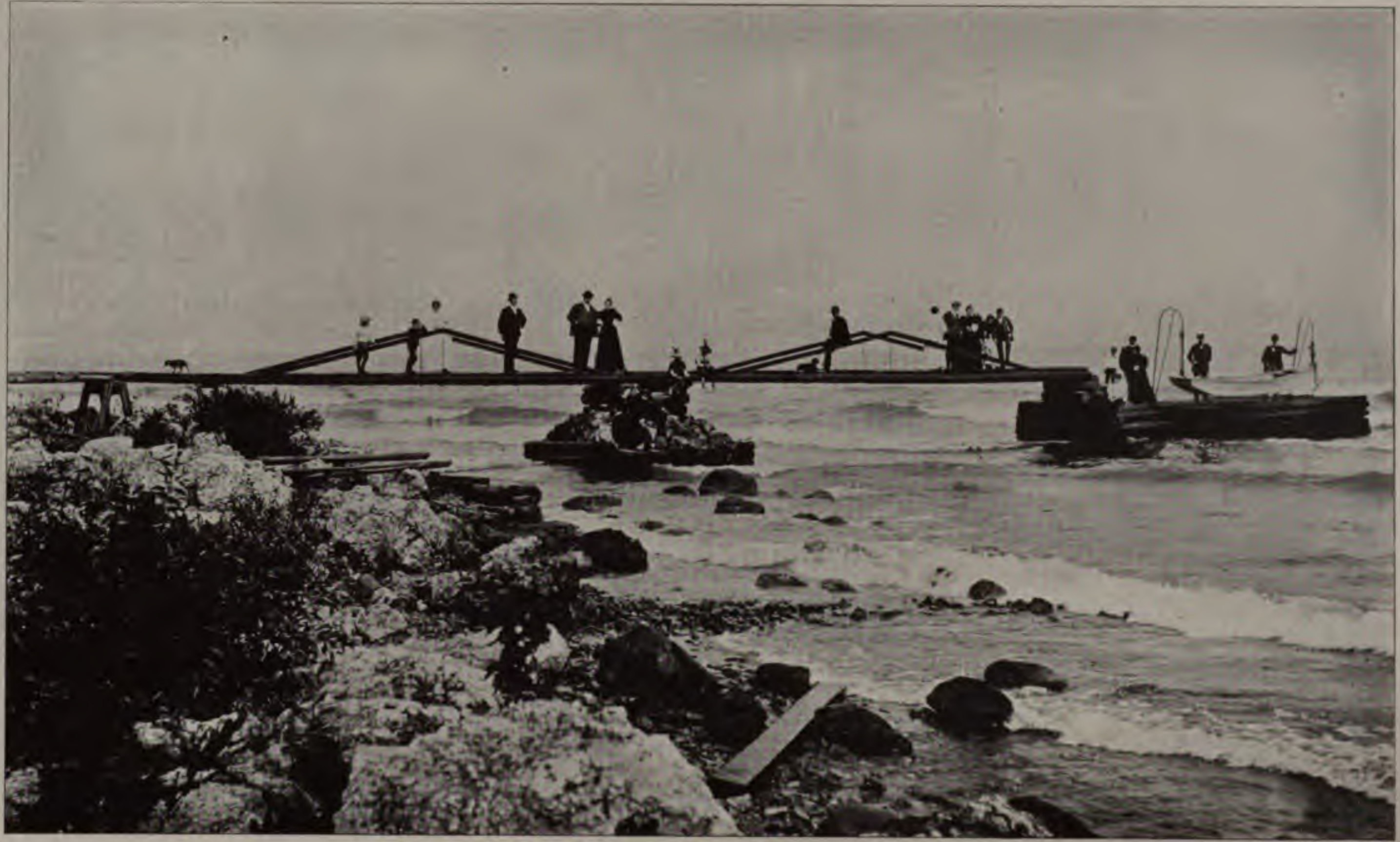
TABLE VIII.—FORMER LAKE BEACHES IN MONROE COUNTY.

Name of lake.	Outlet.	Location of ice dam.	Name of beach.	Elevation of beach in Monroe county.	
				Above tide.	Erie level.
1. Maumee—					
a. Van Wert stage	Fort Wayne	Defiance and Cleveland moraines	Van Wert	793	220
b. Leipsic stage	Fort Wayne and Imlay	Detroit moraine	Leipsic	783	210
2. Whittlesey	Tyre Ubly	Port Huron moraine	Belmore	743	170
3. Arkona	Spillways, Huron county	Between Port Huron and Alcona	Arkona	694	121
4. Warren—					
a. Forest stage	Pewamo	Alcona and Hagensville	Forest	658	85
b. Grassmere stage	Pewamo and-?	Hagensville and northward	Grassmere	615	42

This table has been revised by Leverett and Taylor. L.

§ 14. Lake Erie.

The withdrawal of the ice sheet from the St. Lawrence valley, opened an outlet for the great lakes to the east and the level of Lake Warren fell sufficiently for Erie to separate from Lake Huron. The three upper great lakes were still confluent, forming the great Lake Algonquin which drained into Lake Erie as at present. The still further retreat of the ice from the Ottawa valley, opened an outlet through Georgian Bay, Lake Nipissing and the Mattawa valley, lowering the level of Lake Algonquin to what Taylor has named Nipissing Great Lake. During the existence of this latter lake its drainage was through the Ottawa River, and Lake Erie alone drained into the Niagara River, and supplied the water for the falls. During this time the level of Lake Erie was lower than now. A differential elevation of the region to the north finally cut off the flow through the Nipissing-Mattawa River and the St. Clair and the Detroit rivers again became the line of drainage bringing the present great volume of water into Lake Erie. The elevations and fluctuations of the level of the lake, so far as data have been obtained, are given in the preceding chapter. It seems necessary to conclude from the nature of the Warren beaches that the prevailing wind was from the east or northeast. During the Erie stage it has been from the opposite direction and, although there is a sand ridge bordering the lake for a considerable distance, the sand has not generally encroached upon the land. Between Stony Point and Point aux Peaux there occurs the outcrop of dolomite previously referred to and for this distance there is a gravel beach of rather angular fragments. (See Plates XII and XIV.) The crest of the ridge here is about six feet above the water level and from 30 to 35 feet back from its edge, making the slope quite steep. For the greater portion of the distance between the points there is a belt of sand from five to twenty feet broad, which skirts the water's edge, and in places extends well up the gravel slope. In the water itself there is a strip of fine to coarse gravel, mixed with sand. Landward from the crest of the gravel ridge the inclination downward is more gradual, giving a slope from 50 to 60 feet in breadth, which passes into a low marshy strip, supplied with water from the lake during times of storm. This marsh is, in general, very extensive, covering thousands of acres, and three areas may be recognized, separated by more highly cultivated land about the mouths of Stony and Otter creeks. These have been converted into hunting preserves



MONROE BEDS AT POINT AUX PEAUX, MONROE COUNTY.

and at certain seasons water fowl are abundant. The Point Mouillée marsh extends from the mouth of the Huron to Stony Point. The Monroe marsh begins about a mile south of Brest and extends to the mouth of Plum Creek. The Erie marsh, with interruptions, extends from near Otter Creek to the Ohio line, broadening in places and including patches of open water. Figs. 5 and 8 (p. 199) give views of the last two regions. Shelving off gradually from the beach there is a strip of sand which extends lakeward. The three fathom (18 foot) contour upon the government chart extends out 4½ miles from the north cape of Maumee Bay, and gradually approaches the beach until opposite Stony Point and Point aux Peaux, where it is but one-sixth of a mile out. Northeastward it again pushed lakeward by the deposits from Mouillée Creek and the Huron River.

§ 15. Recent submergence.

Extending backward from the lake for a distance of three to four miles, the Huron is practically a stagnant stream, with an ebb and flow as the easterly winds drive the water in from the lake. A difference of two feet in the level of the water in this part of the river may thus be produced. The Lake Survey chart gives the soundings for a mile back from the mouth, which in the channel range from 10 to 16 feet. Residents say that there are holes in the bed 25 feet deep, from one to two miles back. In an early day lake craft were built at Rockwood, four miles from the lake, and with a little dredging this village could be made a lake port. In its present condition, with no current, the Huron is incapable of cutting such a channel. Further, it meanders over this low plain, showing that at one time there was some cutting and hence some current. Its condition is that of a "drowned stream." The same phenomena are shown, to a greater or less extent, by all the streams which enter the lake from Monroe county. The Raisin empties into the lake by several mouths, the central one of which was converted into a canal by the general government in 1835. A view of this is shown in Fig. 4, giving one a good impression of the inundated appearance of the region. One of the channels to the south of the canal, for a distance of two miles, averages 8½ feet in depth. Back from the lake ¼ mile a depth of 12 feet is shown upon the chart, while in the lake itself the depth is but two to three feet. Referring to the Raisin the coast chart says, "depths at this harbor vary but little from year to year, but dredged channels outside of piers are not permanent." It is probable that the ebb and flow from the influence of the lake serves to keep the channels open, but could not have originally produced them.

Another good illustration is furnished by Halfway Creek, which empties into North Maumee Bay in the southeastern part of the county. Attention was called to this in 1873 by Gilbert in the Ohio report.* Slack water was said to begin seven miles from its mouth. One-half mile from the bay the stream is sixty rods wide, with a central channel four rods wide, fifteen feet deep, and with its banks seven feet under water. Back where the slack water is first noticed the channel is twenty feet wide and six feet deep. The lake chart now shows a well defined submerged channel running back three miles from the bay and averaging 9.4 feet deep, with a maximum of 14 feet. This channel extends into the bay, giving soundings of 7, 10, 8 and 13 feet, through a strip over which the water ranges from 4 to 5 feet. Similar phenomena have been observed by Taylor in the streams which empty into the Detroit and St. Clair Rivers, and into Lake St. Clair.†

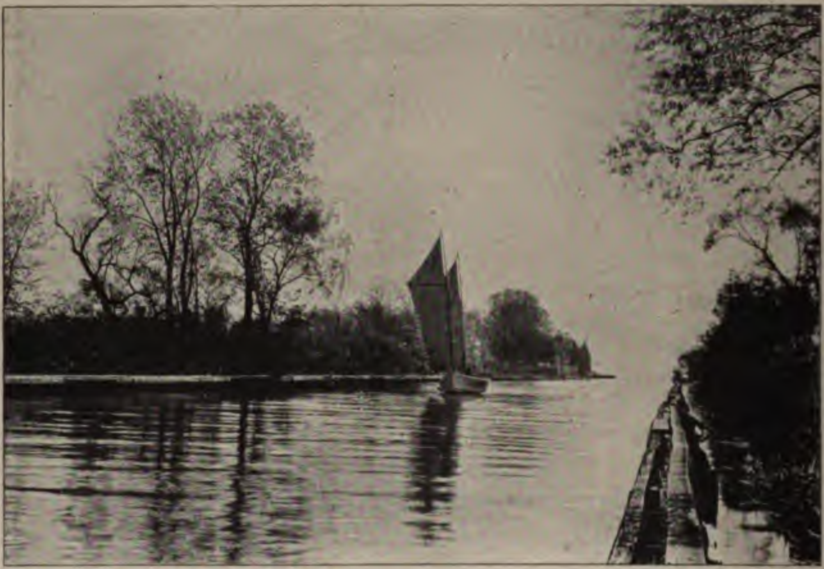


Fig. 4. View of the government canal, near Monroe, opening into Lake Erie. The view gives one an idea of the inundated "drowned" appearance near their mouths of all streams which empty into Lake Erie.

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*Vol. I, Geology, page 555.

†Proceedings Amer. Assoc. for the Ad. of Science, 1897.

The explanation is that all these streams, in comparatively recent time, flowed to a lower base level and were thus given sufficient velocity to cut their channels and erode their banks. According to the conclusions of the above author this occurred during the Nipissing stage, while the drainage of Lakes Superior, Michigan and Huron was through the Ottawa River, leaving the bed of the Detroit River practically empty and, probably, much lowering the present level of Lake Erie.* When the present drainage was restored the strip of land bordering the river and lake would be again covered with water, much of the beach would be rendered marsh and the mouths of the rivers, for a considerable distance back became submerged, *drowned*, as shown in Fig. 4.

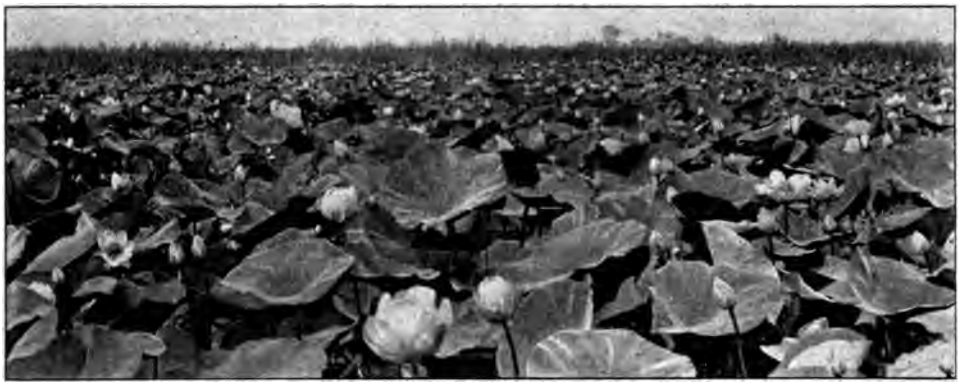

Fig. 5. Lotus bed in the marsh near Monroe. The marsh is due to recent submergence by the lake. Photographed August, 1890.

E. L. Moseley has shown† that this recent submergence accounts for the fact that the plants of the islands north of Sandusky Bay are the same as on the shore. He also calls attention to the fact that upon these islands are caves whose stalactites extend into the water, while the stalagmites are below the water 3 or 4 feet, and gives data regarding submergence of walnut stumps, etc.

D. Post-Glacial Warping.

§ 16. Recent production of stony ridge.

The " stony ridge" which has frequently been referred to as a low anticline in the dolomites, passing from Sylvania northeastward through Monroe, gives evidence of having been produced since the withdrawal of the ice sheet. The deposits of till which overlie the rock appear to be conformable, to a greater or less extent, with the rock strata. There is produced, in consequence, a subdued swell in the surface topography, having a breadth of one-half to two miles and a maximum height of 12 to 15 feet. Had the formation of the rock anticline occurred before the Pleistocene deposits had been laid down we should expect no trace of it in the surface features. In Jefferson and Chautauqua counties of New York, Gilbert found similar low anticlines which he believed to be of post-glacial origin. These were described before the American Association for the advancement of science under the title "Some New Geological Wrinkles."* They were believed to have been caused by the lateral expansion of the superficial rock-strata as their temperature rose in consequence of the post-glacial amelioration of climate.

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*Origin of the Gorge of the Whirlpool Rapids at Niagara. Bull. Geol. Soc. of Amer., Vol. 9, 1898, page 84.

†The Lakeside Magazine, Lakeside, Ohio, April, 1898, Vol. I, pp. 14-17.

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*Proc. Amer. Assoc. for the Ad. of Science, Vol. XXXV. 1886, page 227.

CHAPTER VII.

SOILS AND SUBSOILS.

A. *Nature, Origin and Varieties.*

§ 1. Preglacial soils.

The different types of soil and their formation may be explained most simply by discussing first the effect of the various soil producing agencies upon the bed rock of the county. In determining what change occurred and what substances were produced during the countless ages that these rocks were exposed to the action of the air, rain and frost, it will be possible to bring into view again the original soil materials, with which the rocks were covered, and of which they were so thoroughly dispossessed by the ice sheet. One of the simplest transformations of rock into soil took place in connection with the St. Clair shale, in the northwestern part of the county. The material of which this formation is composed represents the indestructible elements of land areas, carried to the off shore region by streams, waves and ocean currents. It was completely altered, hydrated and deprived of all soluble ingredients. When elevated and exposed to atmospheric and aqueous agencies the principal change was purely a physical one, resulting in its softening and disintegration. There would result a heavy, compact clay soil. Other materials similarly introduced, would give character to the soil and add greatly to its fertility. Organisms which secrete calcium carbonate from the sea water would have become embedded in the ooze of the sea bottom and would add this substance, along with sulphur and iron. In weathering the iron would oxidize and stain the soil a brown or yellow. There must have existed then in the northwestern part of Milan township and adjoining portions of Lenawee and Washtenaw counties a dark brownish yellow or green, compact clay soil possessed of considerable fertility and lasting qualities. To the east of this small area, over the Traverse belt (see Pl. I), a somewhat similar soil resulted from the disintegration of the shales of this formation. It was, however, of a more bluish color and much richer in calcium carbonate because the shales themselves are richer in this substance and because of the interstratified layers of limestone.

A far greater change than that just described would take place in the case of the pure limestones of the Dundee formation which after exposure for a very great period would be unrecognizable. This alteration results largely from the solution of the carbonates of calcium and magnesium. Pure water cannot dissolve much of either of these substances, but when it contains carbon dioxide gas these carbonates are readily taken into solution as bicarbonates in proportion to the amount of this gas present. Ordinary rain water contains from .22 to .45% of this carbon dioxide by volume, but after percolating through a bed of vegetable mould this amount may be greatly increased. Expressed chemically the change by which the calcium carbonate is thus readily taken into solution is shown in the following equation:

$Ca\,CO_3 + H_2O + CO_2 = Ca\,(H\,CO_3)_2$.

In solution the bicarbonate is carried to the sea where the myriads of organisms may break up this unstable compound, retain the calcium carbonate and liberate the carbon dioxide which will escape into the atmosphere to be again utilized in the destruction of the limestones exposed to its influence. By the leaching out of the carbonates the impurities present in the limestone are gradually concentrated and there results a mealy, siliceous clay, generally stained more or less red with iron oxide. Looking at the composition of one of the beds in the Christiancy quarry:

Calcium carbonate	86.80%
Magnesium carbonate	11.60
Iron and alumina	.12
Silica	1.10

it will be evident that the proportions of silica, iron and alumina will increase in the residue as the carbonates are slowly dissolved. The percentages of the latter may be reduced to simply a fraction of one per cent, or to a mere trace. Usually, however, the amount of carbonate left behind is considerable, and there results a calcareous soil. One foot of such soil might represent the destruction of one hundred feet of limestone, involving an enormous period of time. The following analyses from Merrill's "Rocks, Rock-weathering and Soils" (page 359), show at a glance the changes that have thus been produced in a bed of pure Trenton limestone:

	Unaltered limestone.	Soil from same.
Silica (SiO_2)	0.44%	43.07%
Alumina (Al_2O_3)	0.42	25.07
Ferric oxide (Fe_2O_3)		15.16
Lime (CaO)	34.77	0.63
Magnesia (MgO)	Trace.	0.03
Potash (K_2O)	Not determined.	2.50
Soda (Na_2O)	Not determined.	1.20
Carbon dioxide (CO_2)	42.72	Trace.
Water and organic matter	1.08	12.98

By an exactly similar process the dolomites which overlie and underlie the Sylvania sandstone gave rise to a soil in every respect similar. These changes are seen to be in progress at the Woolmith, Raisinville, Davis,' Cummins' and Plum Creek quarries, where the upper layer is softened and whitened and has a mealy look and gritty feel. No appreciable quantity of such soil has been formed, however, since the retreat of the ice, thus testifying to the recentness of this event or to the extreme slowness with which this change takes place. (See Pl. III.) A much simpler change would have occurred in the case of the Sylvania bed, which consists so largely of pure quartz grains. The small amount of calcium and magnesium carbonate which serves as a weak cement, would be dissolved and there would be formed a loose bed of sand, which from the absence of iron must have long remained of a pure white color. Such a soil could have supported only the scantiest vegetation and would eventually become stained with organic matter. It will be seen that the soil deposits which mantled the rock before the glacial episode were dependent for their character directly upon the bed rock itself and could have been traced by imperceptible gradations into it. Clay soil, with more or less silica and iron, covered the greater part of this county, gradually growing darker and heavier towards the northweastern part of Milan. The clay areas were separated by a white sand belt, diagonally crossing the county from southwest to northeast, and varying in width from one-half to four miles.

§ 2. Glacial subsoils.

No sharp line of division can be drawn between soil and subsoil, but by the latter term is commonly meant those loose deposits which are beyond reach in the ordinary processes of cultivation, say from eight to twelve inches deep. The subsoil of Monroe county consists very largely of the previously described till, the "ground moraine" of the great ice sheet. This consists of compact, unstratified, stony clay produced by the grinding of the bed rock over which the ice sheet moved and of the fragments which the ice was transporting. Without doubt the preglacial soils formed enter into the composition of this till to a greater or less extent. A deposit with such a history must obviously contain the greatest possible variety of materials, and be somewhat independent of the underlying rock strata. Such soils have been termed "residuary soils," or "soils of transportation," to distinguish them from the previously described "soils of disintegration." The former are characteristic of glaciated regions, the latter of regions not subjected to such ice action within recent geological time. Prof. W. O. Crosby has made a mechanical analysis of the till found in the vicinity of Boston and finds it to consist of 25% small pebbles, 20% of common sand, 40 to 45% of exceedingly fine sand, essentially quartz, and but 12% genuine clay, (alumina). It is quite probable that this represents approximately the composition of Monroe county till. Lenticular masses of stratified sand are found embedded in the clay and less frequently layers of gravel. Near the surface, within reach of percolating surface water, the iron compounds become oxidized and the till assumes a yellow, brown or red color. Otherwise it is of a characteristic blue color. At Dundee the discoloration of the clay is said to extend to a depth of 14 feet. In some of the stream cuts in Milan township the alteration of the till extends from 1½ to 3 feet only, and this would perhaps represent an average for many portions of the county. In Sec. 33 of Berlin there is said to be 15 feet of light colored clay and 5 feet of blue clay above the rock.

In many portions of the county the subsoils consist, in part, of the lake sediments and beach deposits described in the preceding chapter. A phenomenon for which we have no explanation at hand, was reported by a considerable number of farmers. They assert that, in the case of the isolated sand knolls, common about the margins of the sand belts, the underlying clay is blue and its surface the reverse of that of the upper surface of the sand, that is, concave. This gives the mass of sand a lenticular form and water accumulates in the clay basin so that such knolls are very damp and backward in the spring. They can be drained by simply cutting a ditch through the rim of this basin upon the lower side. Captain Richard Ingersoll, Sec. 22, Dundee, says that the clay upon his lower land can be worked two weeks earlier in the spring than can these knolls. The clay encountered beneath the sand is reported as hardpan. This phenomenon was reported in Secs. 26 and 18 of Dundee and in Raisinville and Summerfield townships.

§ 3. Post-glacial soils.

Without attempting too fine a classification we may say that the Monroe farmers have to deal with five types of soil, which may shade into one another by imperceptible gradations; sand, clay, loam, silt and muck. From what has just been presented the source of the materials for these soils and the method of their formation will be readily comprehended.

(a). Sand and gravel. The great belts of sand, with limited patches of gravel, shown upon Pl. VII and described in the preceding chapter, have been produced by the wave action of the various bodies of water which covered the region after the withdrawal of the ice sheet. About the margins of this series of lakes and for some distance lakeward where the water continued shallow, the waves loosened and softened the till. A sorting of this material began at once, the coarser sand grains and small pebbles were worked shoreward and at times of the heaviest storms, were tossed back upon the beach in the form of a continuous ridge. The retreating wave, when its force had been spent, would drop first the heavier pebbles and carry back for a short distance the sand particles. In this way the beach ridge would be formed of gravel mostly, with a belt of sand upon the lake side. The separate particles, in the course of a year, would be moved backward and forward many times, some of them traveling miles, and owing to mutual attrition would have their corners and edges rounded. In certain places, out from the beach, as in Secs. 21, 22, 15 and 16 of Dundee the force of the waves was not sufficient to move the pebbles shoreward, the sand and clay particles only were removed and the pebbles accumulated on the till. For the same reason they seem to congregate wherever water drips upon a soil through which pebbles are disseminated. While the beaches of Lake Maumee, Whittlesey and Arkona were forming, a lake deposit was being spread over the central and eastern part of the county which covered the till and the boulders lying upon its surface. When the waters had fallen to the level of Lake Warren, the wave action would be directed very largely against this later deposit, instead of the till itself, and would find comparatively little material from which to construct a gravel beach. For this reason we find more gravel in the Belmore, less in the Arkona, and still less in the Warren beaches.

From the distribution of the sand over the region to the west of the Forest and Grassmere beaches it is to be inferred that the prevailing and heaviest winds during this stage were from the east, northeast, or southeast. As the beach ridge of sand was formed by the action of the waves, its loose particles after drying would be seized by these winds and gradually moved landward, until the belt of sand was from three to seven miles broad. It is just this action that now occurs along the eastern shore of Lake Michigan owing to the prevailing northwest winds, while the western shore is comparatively free from such sand accumulation. The sand from the Warren beaches was thus spread over thousands of acres of land, impoverishing the soil and those unfortunates who are compelled to get their living from it. Low cabins, puny barns, bony stock, poorly clad and half starved children; all are because the prevailing direction of the wind, a few thousand years ago, was easterly. At present the prevailing direction of the wind is from the opposite point of the compass and the Lake Erie sands are not encroaching upon the fertile soils adjoining. To summarize then, the sand and gravel of the county were derived originally from the crystalline rocks to the north and east, washed out of the till by wave action around the margins of the lakes and still further distributed by the wind.

(b). Clay. While the action just described was in progress in the littoral region of the lakes, the finer particles of sand and alumina were taken in suspension and carried lakeward by the waves and currents. This material would settle very slowly into the deeper and quieter portions of the water and form the clay deposit previously referred to as covering the bottom of the lake. This would fill up all irregularities of the till surface and slope very gradually and evenly toward the southeast. The particles were so nearly homogeneous in size and distribution that no distinct stratification is visible. The vegetable growth upon the lake bottom became embedded in the clay and gave it a dark color. This deposit would necessarily be thinner in the western and thicker in the eastern part of the county, where it covers the surface boulders. That which was originally deposited over the central portions of the county was very largely removed, as the waters receded, and was carried further eastward. This clay is very sticky when wet, consists of alumina and silica in finely divided particles, contains enough iron to burn red and was derived from the till. Small streams entering the lake from Lenawee and Washtenaw counties would contribute some sand and clay to the Monroe deposits, but they were derived from the surface till of these regions.

(c). Loam. This term is applied to a mixture of sand and clay, which either owing to the proportions of the ingredient, or to the size of the constituent particles, is looser and less compact than clay itself. When wet it is not so sticky, and upon drying does not bake and crack. As the proportions of clay and sand differ, varieties are distinguished which graduate into one another, and into other types of soil. When the plant food products are present it forms an ideal soil, because of the ease with which it can be worked and of its ability to conserve just the proper amount of moisture for plant growth. Owing to the presence of organic matter it is very commonly of a dark color. Narrow strips of this soil occur along the margins of the clay and sand belts where the two have become mechanically mixed through the action of wind and water.

(d). Silt. Along the margins of all the streams, constituting their flood plains, is a deposit very similar in its physical properties to loam. It usually differs from it, however, in having a much greater variety of material present, since it represents the surface wash from all the regions drained by each particular stream. It is distinctly stratified and contains the shells of both water and land snails and other molluscs. Owing to its great fertility it supports an abundant vegetation which gives it a dark color. The larger streams furnish the broader areas of this type of soil, and in some regions dikes have been constructed around the fields to shut out the streams completely at times of flood. In composition the typical river silt consists of 50 to 70% of sand, about 10% each of alumina and organic matter, with varying quantities of iron, calcium, magnesium, potash, soda and phosphorus. Their general nature is shown by the two analyses* given below from the bottom lands of the Raisin just over the western boundary of the county, at Deerfield. The first analysis is of silt which had been under cultivation for 40 years, without manuring, the second represents the "virgin soil." The timber in both cases is ash, basswood, hickory, walnut and oak.

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*"Michigan Soils." Bulletin 99 of the Michigan Agricultural College, page 6.

	Cultivated.	Uncultivated.
Sand and silicates	58.17	62.42
Alumina	6.48	10.64
Oxide of iron	7.62	3.42
Lime	1.92	2.10
Magnesia	1.43	1.59
Potash	1.84	2.05
Soda	1.20	1.19
Sulphuric acid	.32	.24
Phosphoric acid	.40	.41
Organic matter	*10.97	+9.39
Water	9.45	6.08

*Nitrogen =.42
+Nitrogen =.37.

(e). Muck. One characteristic of a glaciated region is the presence of innumerable basin like depressions, in which spring and surface water may accumulate, but from which it cannot readily escape, except by evaporation. Many such spots are found in the sand belts, where the sand is thin and underlain by clay. Small lakes are here formed in which plants, drawing their sustenance from the water and air, get a foothold and eventually add their remains to the soil of the bottom and margin. Coarse varieties of moss presently start, which dying beneath and growing above prepare a bed for the rushes, the water lilies, and the water-loving shrubs. Through the agency of water fowl animal life might be introduced, the decay of which would furnish other ingredients to the soil accumulation upon the bottom. Some clay and sand would be washed in from the surrounding region, so that through all these agencies the lake would be slowly filled and converted into a marsh. New types of plant life would now find suitable conditions, the filling process would continue and a meadow finally result, capable of cultivation. The black, spongy, carbonaceous mass, resulting from the alteration and partial preservation of the organic matter, is called *peat* when practically pure. Usually it is mixed with clay and sand and is then known as *muck*. It is rich in nitrogen and phosphorus, but does not contain sufficient body to serve as a soil for most plants. The total amount of such soil in the county is not great although small areas are numerous in certain regions. A cranberry marsh covering 112 acres is located in the S. E. ¼, Sec 24 of Summerfield township, belonging to Clayton Everett, of Toledo. This is flooded in the spring as shown in Fig. 6 but is drained and later irrigated by numerous wells, from which the water is pumped by windmills. An extensive peat bed occurs in Sec. 9 of London township, 60 acres of which belong to the Ilgenfritz Nursery Co., of Monroe. A crop of *Sphagnum*, the moss concerned mainly in the production of peat, is harvested from it each season and used in packing about the roots of nursery stock for shipment. It holds moisture well, is light and does not "heat." In 1838 Hubbard reported a soil of fibrous peat one to two feet thick as covering 18 sections in Ida, 9 in Summerfield and 5 in Whiteford.

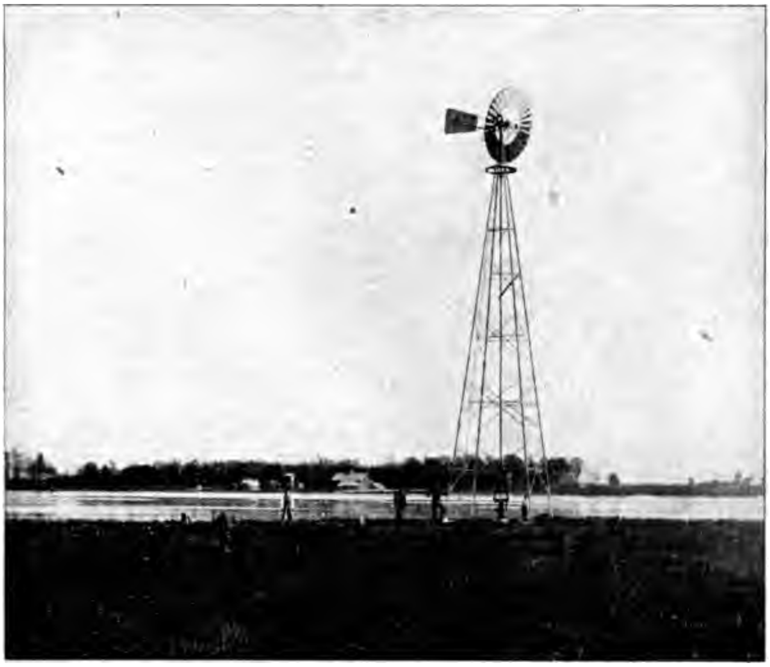

Fig. 6. View of extensive cranberry marsh when flooded in the spring. Sec. 24. Summerfield Township.

B. *Relation of Soils to Vegetation.*

§ 4. Fertility.

The bulk of all tissue found in the higher plants consists of carbon and water in chemical combination. The carbon is derived from the carbon dioxide of the atmosphere, being separated from its oxygen by the green coloring matter, known as chlorophyll, with the energy of sunlight. The water is derived from the soil mainly through the agency of roots. By combining chemically this carbon and water in certain proportion starch is made. From this

	Cultivated.	Uncultivated.
Sand and silicates	58.17	62.42
Alumina	6.48	10.64
Oxide of iron	7.62	3.42
Lime	1.92	2.10
Magnesia	1.43	1.59
Potash	1.84	2.05
Soda	1.20	1.19
Sulphuric acid	.32	.24
Phosphoric acid	.40	.41
Organic matter	*10.97	+9.39
Water	9.45	6.08

* Nitrogen =.42
+ Nitrogen =.37.

(e). Muck. One characteristic of a glaciated region is the presence of innumerable basin like depressions, in which spring and surface water may accumulate, but from which it cannot readily escape, except by evaporation. Many such spots are found in the sand belts, where the sand is thin and underlain by clay. Small lakes are here formed in which plants, drawing their sustenance from the water and air, get a foothold and eventually add their remains to the soil of the bottom and margin. Coarse varieties of moss presently start, which dying beneath and growing above prepare a bed for the rushes, the water lilies, and the water-loving shrubs. Through the agency of water fowl animal life might be introduced, the decay of which would furnish other ingredients to the soil accumulation upon the bottom. Some clay and sand would be washed in from the surrounding region, so that through all these agencies the lake would be slowly filled and converted into a marsh. New types of plant life would now find suitable conditions, the filling process would continue and a meadow finally result, capable of cultivation. The black, spongy, carbonaceous mass, resulting from the alteration and partial preservation of the organic matter, is called *peat* when practically pure. Usually it is mixed with clay and sand and is then known as *muck*. It is rich in nitrogen and phosphorus, but does not contain sufficient body to serve as a soil for most plants. The total amount of such soil in the county is not great although small areas are numerous in certain regions. A cranberry marsh covering 112 acres is located in the S. E. ¼, Sec 24 of Summerfield township, belonging to Clayton Everett, of Toledo. This is flooded in the spring as shown in Fig. 6 but is drained and later irrigated by numerous wells, from which the water is pumped by windmills. An extensive peat bed occurs in Sec. 9 of London

TABLE IX.—PERCENTAGE COMPOSITION OF AIR-DRY FARM PRODUCTS. (WOLFF.)

Substance.	Water.	Ash.	Potash.	Soda.	Magnesia.	Lime.	Phosphoric acid.	Sulphuric acid.	Silica.	Chlorine.	Sulphur.
Wheat, grain	14.3	1.77	.55	.06	.22	.06	.82	.04	.03	....	.15
Wheat, straw	14.1	4.26	.49	.12	.11	.26	.23	.12	2.82	....	.16
Oats, grain	14.0	2.64	.42	.10	.18	.10	.55	.04	1.23	....	.17
Oats, straw	14.1	4.40	.97	.23	.18	.36	.18	.15	2.12	....	.17
Barley, grain	14.5	2.18	.48	.06	.18	.05	.72	.05	.59	....	.14
Barley, straw	14.0	4.39	.93	.20	.11	.33	.19	.16	2.36	....	.13
Rye, grain	14.9	1.73	54	.08	.19	.05	.82	.04	.03	....	.17
Rye, straw	15.4	4.07	.76	.13	.13	.31	.19	.08	2.37	....	.09
Corn, grain	13.6	1.23	.33	.02	.18	.03	.55	.01	.03	....	.12
Corn, stalks	14 0	4.72	1.66	.05	.26	.50	.38	.25	1.79	....	.39
Buckwheat, grains	14.1	.92	.21	.06	.12	.03	.44	.02	....	.02	....
Peas, seeds	13.8	2.42	.98	.09	.19	.12	.88	.08	.02	.06	.24
Peas, vines	14.3	4.92	1.07	.26	.38	1.86	.38	.28	.28	.30	.07
Beans, seeds	14.1	2.96	1.20	.04	.20	.15	1.16	.15	.04	.08	.23
Beans, plants	18.0	5.84	2.59	.22	.46	1.35	.41	.01	.31	.81	.22
Potatoes, tubers	75.0	.91	.56	.01	.04	.02	.18	.06	.02	.03	.02
Turnips	90.9	.75	.30	.08	.03	.08	.10	.11	.02	.03	.04
Sugar-beets	81.6	.80	.40	.08	.07	.05	.11	.04	.03	.02	....
Sugar-beet tops	89.7	1.80	.40	.30	.33	.36	.13	.14	.06	.10	....
Red clover hay	16.0	5.65	1.95	.09	.69	1.92	.56	.17	.15	.21	.21
White clover hay	16.0	6.03	1.06	.47	.60	1.94	.85	.53	.27	.19	.27

degree of comminution the greater is the total surface available for retaining moisture by what is known as capillary attraction. This moisture is spread out as a delicate film over the soil particles, so that the finer these particles are the greater is their combined surface, the more water are they capable of holding, and the more tenaciously is it retained for plant use. A cubic foot of compact limestone has 6 square feet of surface, or 864 square inches, but if sawed into 8 equal cubes, 6 inches upon a side, it possesses 1,728 square inches of surface. If cut into one inch cubes the total surface would be 10,368 square inches, or twelve times as great as the original surface of the cube. Similar treatment of each one inch cube would enormously increase the total surface, and the principle would be the same if the particles were of irregular shape, as is true in the case of soil. It has been estimated that a gram of soil contains from 2,000,000 to 15,000,000 individual granules, depending upon whether we consider a sandy or a clayey soil and the combined surface must be astonishingly great. An estimate made by Whitney gives a cubic foot of soil a surface of 50,000 square feet. If the soil is too loose and open, as in the case of sand, moisture is not properly conserved. Upon the other hand if the soil particles are too fine, as in a very compact clay, too much water is retained for the proper aeration of the roots and the perfect development of the plant. It must now be apparent why the loams and silts are the best soils, for it comes both from the standpoint of texture and the greater variety of material which they contain.

§ 5. Fruit culture.

The clay soils of Monroe county are rich in calcium carbonate owing to the prevalence of limestone in the county and to the north. With the favorable climatic conditions the grape grows luxuriantly in such soil and attains a high degree of richness. So abundant was this fruit along the river from Monroe to Dundee that the *Namet Cybi* of the Indians became *La Riviere aux Raisins* of the early French settlers. In a paper read before the Pioneer Society in June, 1883, Judge I. P. Christiancy thus describes the remarkable growth of the wild grape. The river, he says, was so called

> "from the immense quantities of wild grapes along its banks, which as late as 1843 and 1844 I saw growing on the Macon Reserve along this river and the Saline and Macon where the forest was still untouched, over the tops of the tallest forest trees; some of the vines being from six to eight inches through; which, after climbing to the tops of the trees, dropped branches to the ground, which again took root and made an inextricable mat of vines, such as I have never seen elsewhere except in the tropics."*

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*Michigan Pioneer Collections, Vol. 6, 1883, pages 362-3.

With such a variety of soil and a favoring climate, conditions are found suitable for the growth of other fruit, besides the grape, but Monroe cannot be said to rank high in this regard, when it is compared with other counties of the state. The following table shows the number of bushels of fruit produced in the various townships during the season of 1898, as given in the Farm Statistics for 1898-9. Where no numbers are given the statistics are wanting.

TABLE X.—BUSHELS OF FRUIT PRODUCED IN 1898.

Townships.	Apples.	Peaches.	Pears.	Plums.	Cherries.	Strawberries.	Blackberries.	Raspberries.
Ash..............	1,039	141	116	4	16	15	....	8
Bedford..........	816	432	100	....	....	3,726	456	222
Berlin............	1,264	30	150	66	....	....	....	....
Erie..............	4,078	5,065	1,682	5	190	1,489	181	811
Exeter...........	100	40	30	....	....	....	....	....
Frenchtown.....	225	170	25	30	....	150	100	275
Ida..............	1,417	....	33	5	....	80	68	25
La Salle..........	685	....	190	....	....	....	....	....
London..........	1,345	402	342	52	67	311	17	137
Milan.............	450	75	50	3	....	270	148	30
Monroe..........	947	1,460	741	27	12	289	127	525
Raisinville.......	1,203	521	321	53	27	85	4	51
Summerfield.....	405	480	75	100	....	....	....	....
Whiteford......	2,026	427	1,156	92	279	477	41	103
Totals..........	16,000	9,243	5,011	437	591	6,892	1,142	2,187

An inspection of the table suggests that the best fruit producing townships are in the southern part of the county, including Erie, Bedford and Whiteford. This does not necessarily follow, however, although these townships have a slight climatic advantage over those farther north. It is probable that the nearness of the Toledo market stimulates the raising of fruit and that most of the other townships could make an equally good showing with an intelligent handling of the soils which nature has given them.

§ 6. Farm products.

In the production of the staple farm crops Monroe county ranks well both as to the number of bushels produced and the average yield per acre, the heavier soils being well adapted for the complete development of the cereals. Some localities are capable of

TABLE XI.—MONROE COUNTY FARM PRODUCTS FOR 1898.

Township.	Soil.	Wheat.		Corn.		Oats.		Rye, bu.	Potatoes, bushels.	Beans, bu.	Clover seed, bu.	Hay, tons.
		Bushels.	Average.	Acres.	Bushels.*	Acres.	Bushels.					
Ash	Clay, sand	50,072	20.16	2,239	78,805	1,996	64,947	162	10,299	83	61	2,944
Bedford	Sand	42.113	21.50	2,558	85.642	1,746	59,892	2,151	78,896	177	....	2,447
Berlin	Clay	23,097	18.73	948	41.127	1,008	33,304	100	2,265	....	43	2,047
Dundee	Clay, sand, silt	75,000	18.75	5.500	175.000	5,220	210,000	8,000	2,000	....	....	8,000
Erie	Clay, sand	56,641	24.09	1,733	78,201	1,273	50,633	121	14,352	13	207	3,514
Exeter	Clay, sand	51,936	18.84	2,923	77,363	2,215	63,430	....	10,346	261	....	2,755
Frenchtown	Clay, sand	64,621	19.89	3,085	110,832	2,714	84,675	....	15,157	....	84	3.760
Ida	Sand, clay	58,649	21.71	2,797	101,305	2,076	70,733	1,626	42,873	222	58	2,525
La Salle	Clay, sand	60,522	22.00	2,300	121,450	1,872	59,825	....	15,703	18	163	2,773
London	Sand	33,656	19.94	1,906	64,136	1,472	48,256	2,461	22,029	493	26	2,278
Milan	Clay	54,159	22.34	2,359	110,600	1,651	67,715	....	9,414	232	42	2.361
Monroe	Clay, sand, silt	32,923	22.04	1,311	51,425	1.063	34,988	50	8,449	....	46	1,641
Raisinville	Clay, sand, silt	87,745	22.31	3,829	140,930	2,914	96,842	472	19,633	35	108	3,500
Summerfield	Sand	42,890	21.67	2,752	106,245	1,456	52,474	1,137	59,930	14	10	2,460
Whiteford	Clay, sand	59,133	21.97	3,479	135,825	2,370	92,627	1,546	60,656	195	64	4.120
Totals		798,157	21.04	39,719	1,478,886	31,046	1,089,381	17,826	372,002	1,743	912	47,125

* Shelled.

yielding 30 to 40 bushels of wheat to the acre, but the average yield is but little over half this amount. For 1898 the average for the entire county was 21.04 bushels, Erie township leading with an average of 24.09 bushels to the acre. For 1897 the county average was 20.80 bushels which gave Monroe the rank of 6 when compared with the other 83 counties of the state. The county produces annually nearly a million bushels of wheat, over a million of oats and a million and a half of shelled corn. For the season of 1898 Table XI gives a summary of the yield by townships with the final total taken also from Farm Statistics of Michigan for 1898-9. The sand belts furnish desirable conditions for growing potatoes, beans and buckwheat. It would seem as though the sweet potatoes might also be grown with profit here, but the experiment has been tried only by a very few who report encouraging results. In Sec. 8 of Bedford township ¾ of an acre of heavy sand yielded 12 tons of Hubbard squash. The patches of muck, abundant in certain localities, are generally capable of producing good crops of cranberries, celery and peppermint. The analysis of three typical celery soils will show the composition required for such crops. There must not be over one per cent of iron sulphate present and the muck must not be "sour." ("Michigan Soils," Bulletin 99, Agricultural College.)

	Kalamazoo.	Grand Haven.	Newberry.
Sand and silicates	19.16	24.09	24.56
Alumina	1.40	1.71	2.21
Oxide of Iron	3.94	3.52	1.30
Lime	6 09	5.02	4.18
Magnesia	.81	.62	.75
Potash	.34	.20	.42
Soda	.38	.33	.40
Sulphuric acid	1.31	1.04	.67
Phosphoric acid	.88	.69	.46
Carbonic acid	1.95	1.05	1.10
Organic matter	63.76	61.73	63.75
Water	6.51	10.85	7.31

The rapid development of the beet-sugar industry in Michigan has created a demand for a new crop for which Monroe county soil and climate will be found well adapted. The ideal belt for growing the sugar-beet, so far as temperature alone is concerned, is determined by the summer isotherm of 70° F. This isotherm cuts diagonally across the county, from Toledo northwestward, and the entire county lies between the summer isotherms of 69° and 71°. The season opens early and the rainfall during the period of growth is all that is required. There is but one unfavorable feature relating to the climate and this is the amount of precipitation in September and October, which at Toledo is 2.38 and 2.32 inches respectively. The result of this precipitation at this time is to produce a second growth in the beet, which occasions a certain loss in percentage of sugar. Trial only will demonstrate whether the difficulty is sufficiently serious to involve considerable loss. There are thousands of acres in Monroe county which are well adapted to beet raising so far as soil is concerned. This should be a light loam with a clay subsoil, level but well drained, either naturally or artificially. Thin soils with hard clay subsoils do not allow the tap roots proper development. Wiley, the American authority upon the subject, says, "In general any soil which will give good crops of the cereals and other farm products will produce good sugar-beets." According to the Land Commissioner French, during the season of 1898 Monroe county produced 215½ acres of beets. Previous experiments have demonstrated that the beets are of good quality. Estimates for the state place the amount received for each acre at $53, half of which represents profit. The following paragraph from "Progress of the Beet-Sugar Industry for 1898," by C. F. Saylor, is full of encouragement:

> "Thirty-four samples were received from the State of Michigan, showing a fine average weight, a satisfactory content of sugar, and a high purity. The results of the experimental work in Michigan last year were of such an encouraging nature as to justify the establishment of a beet-sugar factory at Bay City. Other factories are now building, and Michigan gives promise of becoming a strong rival to California in beet-sugar production. Evidently all parts of the State are capable of producing high-grade beets, and the climatic and soil conditions are extremely favorable. The data of this and previous years show beyond question that Michigan is one of the best states of the Union for sugar-beet culture." (Page 151.)

§ 7. Forest growth.

The character and distribution of the timber is determined directly by the nature and distribution of the soils already described. Upon the heavy clay are found oak, ash, elm, beech, hickory, black-walnut, bass, maple, whitewood, and along the water courses, sycamore. A singular belt of hickory, about one mile wide by two to three in length, extended originally in a northeast and southwest direction through Secs. 5, 6, 7 and 8 of Milan township. This region furnishes also most of the beech found in the county. The regions of heaviest sand have but a scanty growth of timber, consisting mostly of yellow, white and burr oak which form the so called "oak openings." In the swampy regions "popple" and tamarack are abundant. North of the Raisin the chestnut is common on the sand belts and extends northward into Wayne county.

The farmers uniformly report this tree as absent south of the river upon the same sand areas, over which it is abundant to the north. It appears that the Raisin has thus far constituted a barrier to the southern progress of this tree. In a preliminary survey of the flora of southeastern Michigan, Prof. C. F. Wheeler of the Agricultural College, in 1890, noted the following 55 trees:

Acer dasycarpum	Silver maple.
A. rubrum	Red maple.
A. saccharinum	Sugar maple.
A. saccharinum, var. nigrum	Black maple.
Aesculus glabra	Ohio buckeye.
Asimina triloba	Papaw.
Amelanchier Canadensis	Shad-bush.
Betula papyracea	Paper birch.
Carpinus Americana	Ironwood.
Carya alba	Shagbark hickory.
C. amara	Bitternut.
C. porcina	Pignut.
C. sulcata	Big shell bark hickory.
Castanea sativa, var. Americana	Chestnut.
Celtis occidentalis	Hackberry.
Cercis Canadensis	Red bud.
Cornus florida	Dogwood.
Cratœgus coccinea	Red haw.
C. coccinea, var. mollis	Red haw.
C. crus-galli	Cockspur thorn.
C. tomentosa	Black thorn.
Fagus ferruginea	Beech.
Fraxinus Americana	White ash.
F. sambucifolia	Black ash.
Gleditschia triacanthos	Honey locust.
Hamamelis Virginiana	Witch hazel.
Juglans cinerea	Butternut.
J. nigra	Walnut.
Liriodendron tulipifera	Whitewood.
Morus rubra	Red mulberry.
Negundo aceroides	Box elder.
Nysa multiflora	Sour gum.
Ostrya Virginica	Water beech.
Platanus occidentalis	Sycamore.
Populus balsamifera	Balsam poplar.
P. grandidentata	Large toothed aspen.
P. monilifera	Cottonwood.
P. tremuloides	Aspen.
Prunus Americana	Wild plum.
P. serotina	Wild black cherry.
P. Virginiana	Choke cherry.
Quercus alba	White oak.
Q. bicolor	Swamp white oak.
Q. coccinea var. tinctoria	Black oak.
Q. macrocarpa	Burr oak.
Q. palustris	Pin oak.
Q. rubra	Red oak.
Rhus glabra	Smooth sumach.
Salix amygdaloides	Western black willow.
S. nigra	Black willow.
Sassafras officinale	Sassafras.
Tilia Americana	Basswood.
Ulmus Americana	White elm.
U. fulva	Slippery elm.
U. racemosa	Corky white elm.

C. Amelioration of Soils.

§ 8. Importance of subject.

Until the unwelcome truth is forced upon their attention probably most farmers look upon their land as an inexhaustible source of wealth, requiring only so much sunshine and moisture and so many hours of physical labor. Their farms to them are like the mythical hen which laid golden eggs without having to be fed upon bullion. In a state of nature the materials drawn from the soil by vegetation, are sooner or later returned to it, with a high rate of interest in the form of organic matter. It is impossible for this to occur when the land is under cultivation, otherwise there would be no advantage in such cultivation. A drain upon the soil is at once started, the nature and amount of which depends upon the character of the crops harvested. Every load of grain marketed, every animal fattened upon the farm means a certain reduction in its resources. It is not sufficient to return the straw and manure in order to make good the loss. This could be done only by again scattering the grain over the fields and restoring to the soil the carcasses of the animals fattened at its expense. Most of the older farmers will recall that the shocks of wheat do not stand as closely now as in former years. It is folly for the farmer, and especially for one who has his fortune still to wrest from his land, to allow his soil to become depleted and barren as has happened in many sections of New England and Europe. Left entirely to itself, in the course of time, the fertility of the land is restored by natural agencies, which it may be well to briefly consider since they will suggest means of artificial amelioration. Some of these agencies have worked with extreme slowness and seem trival, but operating through a long period, their effects have been great and to their action is due the happy, prosperous condition today of many Monroe county homes.

§ 9. Natural amelioration.

(a). Inorganic agencies. The drifting of loose sand by the wind over adjoining clay areas, although frequently disastrous, has produced,belts of loam in the county which are better suited to most crops than either the sand or the clay alone. A similar action has taken place about the knolls and ridges through the agency of surface water, the sand being washed down and spread over the adjoining clay areas. Under cultivation finely pulverized clays are frequently taken as dust into the air and spread over adjoining sand belts, giving them more body and supplying, to a greater or less extent, the variety of materials which they need in order to support the staple crops. These clay particles may be carried beneath the surface by percolating water and become a permanent acquisition of the sand. Rain brings to the soil yearly small quantities of nitrogen in ammonia and nitric acid. From observations extending over a number of years at various stations in Europe it is estimated that the average amount of these two nitrogen compounds per acre is 10.23 lbs. a year, with a range from 1.86 lbs. to 20.91 lbs. This is estimated by King as sufficient to supply the nitrogen required for two bushels of wheat.* Similar observations show that sulphuric acid is also present in rain water, but in smaller quantities. For a rainfall about equal to that of Monroe county the estimated amount is 2¼ lbs. to the acre for each year. Springs may locally add desirable ingredients to the soil, although too great quantities are generally deposited while the spring is active. In case the spring dries up the excess may be removed through the agency of rainwater and the character of the original soil more or less improved.

If one examines a pile of field stone many will be found, which although firm and solid within, are covered with a soft mealy crust, soft enough to be easily removed with the finger-nail. This is particularly true of rocks rich in plagioclase feldspar, hornblende and mica, less so for those containing much orthoclase feldspar and not at all so for the quartzites. This phenomenon is known as a "weathering" and results from the absorption of moisture by the minerals and their chemical disintegration. Both soluble and insoluble compounds result from this action, the former being taken into solution by the rainwater and carried to the streams, while the latter material is added to the soil. Boulders of considerable size may sometimes be found in which this destructive change extends to the center, so that they readily crumble at the touch or may easily be pulled to pieces with the fingers. This decay of the crystalline rocks adds to the soil silica, alumina, calcium carbonate and valuable quantities of soda and potash. When iron is present, even in small quantity, its oxidation and hydration takes place, staining the weathered material brown to yellow. The lasting qualities of glacial soils are due, in part, to this continuous enrichment which they receive from the rock fragments contained. Shaler has attributed the ranker growth of vegetation about surface boulders to this action.† Since this phenomenon may be seen about objects incapable of yielding nutriment to the soil it may be questioned whether the effect is not due mainly to the conservation of moisture and heat by the object. The disintegration of rock masses is greatly facilitated in temperate regions by alternate freezing and thawing of the water which collects in its pores and crevices. It has been determined that even solid granite will absorb .4 of a pound of water for 100 pounds of the rock. Upon freezing this water exerts an enormous disruptive force, producing crevices where none existed and enlarging others already formed. The great Ida boulder shown in Fig. 1 furnishes an illustration at its smaller extremity, where a large fragment has been flaked off in the way described. These crevices allow the destructive atmospheric agencies to operate over a larger and larger surface, thus greatly facilitating complete disintegration. Cleopatra's Needle, which safely withstood centuries of Egyptian climate, has suffered severely from a quarter-century of New York's changes and, in order to be preserved, must be housed as are other exotics.

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*The Soil, pp. 119-120.

†Origin and Nature of Soils, Twelfth Annual Rep., U. S. Geol. Sur., part I, pages 237 and 288.

(b). Organic agencies. Plant and animal agencies have a very important share in the natural improvement of soils already formed, or forming, operating in a variety of ways. In the case of the Ida boulder above referred to, the crevice which has been formed by the frost is now filled with soil in which smaller plants grow every season. In the course of time the wind, or a bird, will leave there the seed of some tree or shrub, which in its growth may completely rend the rock asunder. The accumulation of leaves in such a place, combined with growth in place of lichens and mosses, will furnish carbon dioxide gas and organic acids after their decay. These compounds added to the rainwater will greatly increase its power to dissolve substances from the rocks. Even the refractory quartz yields readily to its power. Hayes has recently cited instances of the solution of pure quartz through the agency of humic acids,* and gives Thenard as authority for the statement that simple humic acid will dissolve .8% of silica. After absorbing nitrogen from the air, however, and becoming azohumic acid it is capable of combining with 7 to 24% of silica, depending upon the quantity of nitrogen used. Compounds are formed which are readily soluble in alkaline carbonate solutions. Where conditions are favorable for the growth of bacteria, compounds may be formed which have a similar effect upon rock masses, thus rendering available to plants a larger quantity of mineral matter. The roots of the coarser plants and particularly those of shrubs and trees penetrate the subsoil to considerable depths, forming channels through which surface water and atmospheric gases may enter, thus carrying downward the action of these agencies. The overturning of trees by tornadoes frequently results in a mixing of soil and subsoil on account of the quantities of earth adhering to the roots. The effect, however, is just as liable to be disastrous as beneficial. Not only indirectly, as just pointed out, but directly through its partial decay, is the soil enriched through various forms of vegetation. The mineral substances required for plant growth are derived from the soil and returned again after the decay or combustion of the material. The carbon, however, which is the basis of nearly all plant products and some nitrogen, in certain cases, are drawn directly from the air, as explained in § 4 of this chapter. The incorporation of vegetation into the soil thus adds to it materials which it did not originally possess and to this extent it is enriched. Not only plant food is thus introduced but the undecayed carbonaceous matter renders the compact soils more porous, less wet and heavy, while the lighter soils are better enabled to retain their moisture. The dark color imparted to the soil gives it the power to absorb more of the sun's heat.

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* [illegible]

In this work of soil amelioration the plants are assisted to a great extent by animals. Charles Darwin in his book entitled "The Formation of Vegetable Mould," first called attention to the important effect of earthworms in working over and loosening up the soil. They, however, work mostly in soil that is already rich and hence needs their help least. Here they are frequently present in surprising numbers but almost or quite absent from heavy clay and light sand. They have the habit of passing through their long alimentary tracts, as they burrow, quantities of earth upon which their digestive juices act. The soil particles are triturated, softened, partially dissolved and finally ejected upon the surface in relatively large quantities. Penetrating to a depth of six to eight feet they bring to the surface the subsoil, thus mixing and deepening the layer of true soil. Darwin estimated from his observations in England that every five years the equivalent of one inch of soil is thus worked over by these lowly creatures (page 171). Their burrows allow atmospheric gases and surface water to reach the lower strata. Further, the earthworm draws into its burrow at night, to a depth of two to three inches, quantities of leaves. Enlargements in its burrow are lined with small seeds and pebbles. The vegetable matter thus introduced in part decays and enriches the soil. When this action is continued for one or more centuries its importance can scarcely be over-estimated. Next in importance to the earthworm may be mentioned in this connection the ant. The former prefers a damp soil while the latter selects one somewhat drier. In excavating their galleries they bring fine particles to the surface, sometimes from a considerable depth, thus securing the desirable mixing of soil and subsoil. Shaler has found the soils of certain fields in Massachusetts entirely altered through the agency of ants, and estimates that one-fifth of an inch of material is annually brought to the surface (page 278). Both animal and vegetable matter is introduced into the soil through their agency and their burrows secure more or less aeration for it. In tropical regions the work of ants is far more extensive, immense quantities of earth being brought to the surface. Branner has very recently described a region in Brazil the surface of which is nearly covered with their mounds, varying in height from 3 to 14 feet and in diameter from 10 to 30 feet.* Their channels were observed to extend to a depth of 13 feet below the surface, and through them surface waters are introduced, hastening the decay of the underlying rock. The larvæ of many forms of insects burrow into the soil and bring about some of the above results, but to a less extent.

In the southern part of Summerfield township Mr. Ezra Lockwood informed the writer that his sandy soil had been very materially improved through the agency of crayfish. These creatures construct long subterranean passages, about an inch in diameter and many feet in length, finally terminating at the surface. Over this entrance they frequently build up a chimney of clay for which it is difficult to assign any particular use. Standing several inches above the low flats they look as though they might be intended to exclude surface water from the burrow, but the crayfish would scarcely object to such water. If it left the mouth of its burrow, in case of surprise the crayfish would have difficulty in retreating, and quite probably the clay which it is desirable to remove in enlarging the entrance is thus heaped up in order to avoid leaving the burrow. The beneficial result noted comes from the mixing of this clay subsoil with the surface sand. In certain places these burrows assist in draining a marshy area and rendering it more tillable. A large number of burrowing animals exercise a similar effect, slight in any particular case but important in the aggregate. There may be mentioned mice, gophers, wood-chucks, rabbits, muskrats, moles, birds, etc., which excavate burrows, mix the soil and subsoil, and introduce beneath the surface more or less organic matter. In all these cases cited the animal forms themselves eventually die and their remains are added to the soil. Valuable mineral and organic compounds are thus introduced which are worked over into plant tissue and finally again into animal. If the bodies still remained of all animal life that has died upon a given area since the close of the Glacial Epoch it is quite probable that the ground would be seriously encumbered with their carcasses.

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*Jour. of Geol., Vol. VIII, No. 2, 1900, pp. 151 to 153.

§ 10. Artificial amelioration.

Nature offers many suggestions to the farmer whereby he may improve the character of his soil which is gradually and surely being impoverished. He may simply imitate the least expensive and most effective of her processes. One of these is the simple mechanical mixing of clay, sand and muck in sufficient proportions to form a loose, dark loam. In many regions this may be done by deep plowing, these different soils frequently overlying one another in close proximity near the surface. Many fields on the outskirts of the Forest and Grassmere beaches contain surface patches of sand and muck surrounded by clay. By means of a cart and scoop in the course of a few seasons these could be mixed and a valuable soil produced. Waiting for nature to accomplish this will seriously postpone the resultant harvest, as she is too dilatory in her methods. What would be supplied to the soil in the course of years through the disintegration of rock masses must be furnished more lavishly when the soil is under cultivation. An inspection of Table IX, § 4, of this chapter, shows that plants draw from the soil potash, soda, magnesia, lime, phosphorus, sulphur, chlorine and silica. Nitrogen in general must also be so obtained, although exceptionally it may be secured from the atmosphere in the way described below. Iron is also a necessary soil ingredient for the complete development of crops, but this along with the chlorine and silica is sufficiently abundant in all soils. Marl, ground limestone and "plaster" will cheaply supply lime, magnesia and sulphur. The earlier geological surveys strongly called attention to the value and availability of marl as a fertilizer. The loss which the soil sustains in potash, soda, phosphorus and nitrogen is more difficult to make good, involving the use of manures and commercial fertilizers. Upon application the State Agricultural College will gladly supply to all their analyses of the fertilizers now upon the market, from which there may be obtained an idea of their relative value for certain soils and crops.

Patches of muck land, which might support crops of cranberries, celery and peppermint are frequently found barren because of an excess of free acid. Such muck smells sour and will turn blue litmus paper to a red color. This condition may be remedied by drainage, loosening of the muck so as to well expose it to the weather, and by neutralizing the acid with marl or wood ashes. In his Report of 1861 (page 194), Dr. Winchell discusses this subject in language well worth reprinting in this connection.

> "Nature has placed it (the material for overcoming the acidity of the muck) in the form of marl, in immediate juxtaposition with the peat which needs its agency. Indeed the farmer can in many cases load his cart with the mixed deposits without even moving his team from their tracks. I hardly know a more striking adaptation of natural means for the accomplishment of a necessary object. The porous nature of our soils suffers their soluble constituents to be carried away to the lower levels where peat and marl are accumulating, and where the growths of ages unknown, have been adding a thousand fold to the nutritive elements brought down from the soils of the contiguous hill slopes. These depositories of agricultural force, a good economy will not fail to appreciate and apply to the recuperation of declining wheat lands."

A practical method of increasing the fertility of soil, through the addition of nitrogen, has long been known to the farmer although few can explain the steps in the process. The procedure is purely an empirical one. If a plant of clover be pulled up and the soil washed from its roots there will be found upon them small irregular lumps, "tubercles." If one of the tubercles be picked to pieces upon a strip of glass and examined with a high power microscope there will be found minute stick like bodies in enormous numbers. These are one-celled plant organisms known as "bacteria" and in some way, as yet unknown, they enable the clover plant to appropriate the free nitrogen of the air. Beans, peas, lupine, and leguminous plants in general are similarly aided by various species of these nitrifying bacteria. Other plants not so assisted are surrounded by a great atmosphere of this nitrogen of which they are unable to appropriate an atom. They may be compared to the wrecked mariner upon a desert island, who famishes for lack of water although surrounded by the great ocean. In addition to the mineral matter taken from the soil and the carbon from the atmosphere, the crop of clover stores up nitrogen derived from the air. The plowing under of such a crop then adds to the soil valuable plant food which it did not possess. If a soil is too poor to produce clover suitable fertilizer may be applied first and then the field sown with clover, preferably one of the coarser varieties. The nitrogen of the soil is in part free and in part in the compounds ammonia, nitrous and nitric acid. nitrates of sodium, calcium, etc. The ammonia which is a valuable ingredient of barn yard manures, is converted into nitrous acid through the agency of bacteria and this is changed into nitric acid, in which form it may be utilized by plants. If the soil is too wet some of these compounds are broken up, the nitrogen returned to the air and the soil to this extent impoverished.

CHAPTER VIII.

ECONOMIC PRODUCTS.

§ 1. Building materials.

A detailed description of the geological features of the various quarries of the county and layers exposed has been given in Chapter IV. At nearly all these localities stone for curbing and rough masonry may be obtained in unlimited quantities. Along the anticlinal ridge in the eastern part of the county the rock is shattered in places and its value much diminished for construction work. The lower layers in the Navarre quarries on Plum Creek are, however, heavily bedded and masses two and a half feet in thickness are being removed. In all the quarries in southeastern Michigan it is found that the surface layers are shattered and thin bedded, probably from the enormous pressure of the ice sheet and subsequent action of the frost. The Monroe beds which lie between the Sylvania sandstone and the Dundee limestone furnish the best building stone in the county. About Ottawa Lake, however, the layers are too thin bedded and their color is not uniform, so that they are desirable only for rough work. Northeastward these beds improve in quality. At the Little Sink, Lulu and Ida quarries good building stone, but no massive blocks are obtained. The blue streaked dolomite previously described as occurring at the Lulu quarry has a thickness of 20 inches, is of a fine texture and would probably take a good polish. Upon exposure to weather the blue color would rust and the rock shows a tendency to check, but for indoor work it might prove of value.

The most massive blocks for building, curbing and flagging are obtained at Woolmith quarry (Chapter IV, § 4), from a very thick bed of silicious dolomite of a light brown color, sold in the market as a "sandstone." Plate II gives a view of some of the blocks of this bed that may be obtained by the use of steam channelers. Masses of almost any desired size may be secured and sawed into shape. Thin dark seams detract somewhat from its value for fronts. According to the Company its crushing strength as determined by Gen. Q. A. Gilmore and Col. Herman Kallman, of the U. S. Engineers' Office in Detroit, is 13,800 pounds per cubic inch. Much of this stone has been used in Detroit during the past five years. The Macon and Dundee quarries furnish some heavy blocks of very pure limestone two to three feet thick, suitable for bridge work. The rock is impregnated with oil which would render it objectionable for many uses. The oil near the surface is lost upon standing, after which the rock grows lighter in color and the oil still contained within would contribute to the preservation of the stone. The sills and cappings of the old court house at Monroe were of this stone and well stood the test of years. About 200 cords of this stone are taken out yearly from each of the two quarries.

§ 2. Quick lime.

Since the early occupation of this region by white settlers lime to supply the local demand has been burned wherever the rock was available. Small openings were made into the upper layers and in the vicinity of outcrops, loose fragments were collected from the surface. The kilns were constructed, whenever convenient, along hillsides so that the rock could be dumped in from above. Their remains are frequently met with along the line of the "Stony ridge" from Ottawa Lake to Stony Point. As early as 1838, according to Hubbard, three kilns were in operation on Plum Creek, burning 900 to 1,000 bushels annually, five at Ottawa Lake, producing 2,500 bushels, and eight kilns upon the Macon, yielding 6,000 to 8,000 bushels annually. At the time of the Winchell Survey in 1859 and 1860 the Macon kilns were turning out about 10,000 bushels annually, and those upon Plum Creek a much greater amount. The chief business, however, was carried on at Raisinville (Grape) where 13 kilns were in operation, each with a capacity of 8,540 bushels. Dr. Winchell estimated that about 295,000 bushels were being produced annually in the county with a value of $36,875. At present writing lime is being burned at but three points in the county. Upon Plum Creek a small kiln of a capacity of 500 bushels is operated by Hugh Gaffny but only enough lime is produced to supply the Gas Company, 1,000 bushels in 1899 and 3,000 bushels in 1898. The rock used is the local dolomite, giving a slow slacking lime. The increasing cost of fuel has seriously interfered with the business. With wood as fuel the time required for burning was 72 hours, but by using alternate layers of fine coal and dolomite this time is reduced to 50 hours. At

Grape S. A. Kring has been operating the quarry up to a recent date owned by Robinson and Taylor, of Detroit. The rock burned is a dolomite which showed upon analysis of magnesium carbonate 45.01%, calcium carbonate 51.69% and of silica 3.45%.* Small quantities of iron, alumina and gypsum occur also. This yields a lime which slakes slowly, does not develop much heat, increases relatively but little in volume and will not take as much sand. This type of lime sets slowly and is preferred by many builders. Mr. Kring operates a continuous, double kiln from which every eight hours 75 bushels of lime may be withdrawn. The industry is continued for eight months in the year with eight hands and three teams, by which the product is drawn to Maybee, Ida and Monroe for shipment. For the past two seasons there have been burned here 35,000 bushels of lime annually, which has retailed at the kiln at 18 to 20 cents a bushel and in car load lots sold for 14 or 15 cents.

An entirely different type of lime is that manufactured at the Macon quarry from the pure limestone. This is of a purer white color, slakes very rapidly, developing much heat and increasing greatly in volume. It is capable of binding together much sand and is consequently said to be "strong." Owing to its "lively" character it is difficult to confine it in barrels. There are four kilns here, but two of which are in repair. These yielded 6,000 bushels in 1898 and 1,000 in 1899. Ordinarily only the two upper beds are used, of which the upper yields the whiter lime. (Chapter IV, § 1). The third bed yields a "livelier" lime than the upper two. The conversion of such limestone ($CaCO_3$) into lime (CaO) is accomplished by driving off the carbon dioxide (CO_2) at a temperature of about 824° F. The markets for the Macon lime are mainly local, but it is regularly supplied to the Southern Chemical Company, manufacturers of wood alcohol at Yuma, Michigan. Considerable lime was at one time shipped to Ann Arbor and Detroit but lack of shipping facilities prevented competition with more favored localities. The Detroit and Lima Northern now passes within a few rods of the quarry and these facilities are in consequence much improved.

Lime has been burned at Woolmith and at Ottawa Lake but the quality at each place was found unsatisfactory. Excellent facilities for manufacturing and shipping a promising variety of magnesian, or dolomitic lime, are found at the Ida quarry. A large double kiln of the continuous type stands upon the edge of the quarry and but a few feet from the Adrian-Monroe branch of the Lake Shore railroad. Lime was burned here up to the time of the last financial depression and has not been since resumed. The best grade is made from the upper six feet of the second bed (Chapter IV § 6). It slakes slowly but is said to be strong for this variety of lime. It hardens into a substance more nearly resembling cement than mortar, becomes fully as hard as limestone itself and well resists the weather. In a private letter from Homer Wilcox, a Jackson dealer in lime, cements, etc., the following estimate is given of this lime.

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*Some of these dolomites might be suitable for basic furnace linings. L.

> "The ordinary quick lime manufactured at Ida is not liked as well as some other limes because it slakes so slowly. When used, however, it furnishes a stronger bond and though slowly setting becomes ultimately harder than the quicklime from Ohio, around Fremont and Genoa, or the darker quicklime from the Marblehead territory. * * * Burned moderately it makes a white, slow-slaking, hard setting lime and though it works cool and sets slowly, when it does set is very strong and resists action of water almost equal to hydraulic cement." (Jan. 28th, 1897.)

From figures furnished to the U. S. Geological Survey at Washington the total value of the lime for this county was $4,520 in 1897, $5,163 in 1896 and $6,675 in 1899. These figures appear to be somewhat below the actual amount produced. It is certain that the amount of this product could be indefinitely increased and of each of the three varieties described.

§ 3. Soda ash limestone.

For the manufacture of sodium bi-carbonate ($Na\ H\ CO_3$) known ordinarily as "soda ash" now being produced in great quantity along the Detroit River, a high grade limestone is required. This should contain from 95 to 99% of calcium carbonate with only small percentages of silica and iron. The carbon dioxide of the stone is driven off by heat as in the ordinary manufacture of lime and is made to combine with the sodium of the salt made use of in the manufacture of the ash. At present most of the rock is supplied by the extensive Sibley quarry near Trenton from their remarkable "9-foot bed." The only formation in Monroe county capable of yielding stone of requisite purity is the Dundee (See Plate 1) and the only accessible locality is on the Macon, northeast of Dundee. It is probable that here are found the identical beds of the Sibley quarry, reduced in thickness and somewhat altered in character, but still exceptionally pure, (See descriptions and analyses Chapter IV, § 1). The limestone here is impregnated with oil which would render it objectionable for the manufacture of soda, but it would seem as though this might be either burned from the stone at a lower temperature than that at which the gas would escape or else washed from the gas in case the oil and gas were driven off together. In the Christiancy quarry the disposition of the water is a serious matter on account of the nearness of the Macon. In describing the quarry it was pointed out that this difficulty would become relatively less as the quarry was deepened and broadened. Another site for a quarry in which water would probably cause still less trouble may be found about 80 rods to the northwest upon land formerly belonging to James Brown, now owned by B. E. Bullock, of Toledo. The rock is said to come to within five to six feet of the surface which would not mean an excessive amount of stripping considering the thickness of the strata that could be worked for one purpose or another.

§ 4. Beet sugar limestone.

The wonderful development of the beet sugar industry in Michigan has still further stimulated the search for higher grade limestone. The specifications required are essentially the same as for the stone used in the manufacture of soda ash. If found at all within Monroe county it must be at the localities mentioned above, which fortunately are surrounded by favorable agricultural regions for the growth of the beets. The stone is burned in kilns and both the carbon dioxide gas which escapes and the lime left behind are utilized in the manufacture of the sugar. The limestone should be compact and hard and not in fine pieces, otherwise it will "bridge" in the kiln and give trouble. For this reason marl cannot be made use of for this purpose. The percentage of silica, silicates and alumina needs to be low, since these will cause fusion in the kilns, the compounds adhering to the sides and "bridging." Magnesia and gypsum are not objectionable in the kilns but they interfere with the filtering and evaporation of the juice. It is said that magnesia may be tolerated up to three per cent. One per cent of moisture in the stone is considered desirable but as much as five per cent is objectionable since it interferes with the burning. A good quality of coke is recommended as fuel rather than coal which may introduce impurities into the lime and gas. The table of analyses opposite is taken from Special Report on the Beet-Sugar Industry in the United States for 1897.

Numbers 1, 2 and 3 were found to be satisfactory, while 4, 5 and 6 are excellent. The analyses of the Macon limestone make a very good showing when compared with these, but it is not to be expected that all the beds will prove equally suitable. The oil will prove an objectionable ingredient unless it can be disposed of in the way

TABLE XII.—COMPOSITION OF LIMESTONE FOUND SUITABLE FOR BEET-SUGAR MANUFACTURE.

Ingredients.	1.	2.	3.	4.	5.	6.
Moisture	4.17	6.25	5.16	.52	1.21	.11
Sand, clay and insoluble matter	3.07	3.17	2.25	2.85	.55	.27
Organic matter	.97	1.12	.86	.30	.41	.15
Soluble silica	.98	.64	.56	.06	.20	.03
Oxides of iron and alumina	.19	.15	.20	.32	.23	....
Calcium carbonate	88.65	87.93	90.03	93.80	96.58	99.10
Magnesium carbonate	.95	.50	.45	1.81	.50	....
Sodium and potassium (Na_2O, K_2O)	.01	....	....	....	....	....
Undetermined	1.00	.24	.39	.34	.32	.34

suggested, or in some better manner. In the manufacture of the sugar the juice of the beet is treated with the lime either in powdered form or as "milk of lime." This lime unites mechanically and chemically with the impurities of the juice after which the carbon dioxide gas, driven from the limestone by heat, is allowed to bubble through the limed juice. A recombination takes place forming the calcium carbonate anew as a flaky precipitate which carries the impurities to the bottom. This calcium carbonate is separated from the juice containing the sugar by passing the latter through a cloth filter. This precipitate has value as a fertilizer and the farmer may bring his beets to the factory and take back a load of this material for enriching his soil. Lime is sometimes further used in recovering from the waste substance known as the "molasses" its final content of sugar. This sugar may equal 15 to 20% of that contained in the beet and is made to unite with lime forming tricalcium saccharate, which may be filtered out. In some of the European factories this sugar is recovered by the use of strontia, derived from the mineral strontianite, a mineral which occurs at several localities in Monroe county, but so far as we yet know only in limited quantities. The strontium is again carefully recovered in the form of the hydrate and after the process is started, simply the loss has to be made good. This loss as calculated by Prof. Wiley, in terms of strontianite would equal 6.25% of the weight of the molasses treated, rather more than the county could supply unless richer deposits are uncovered. For a factory using 300 tons of beets daily it is estimated that from 35 to 40 tons of limestone would be required daily, the exact amount depending upon the purity of the stone.

§ 5. Cement materials.

A widespread and deep seated impression has prevailed for a long time in and about the county that the dolomites of the Monroe beds possess hydraulic properties; that they are capable of producing a cement capable of hardening under water. This has resulted very probably because of their equivalency with the noted "waterlime" series of New York. In his report for 1840 Hubbard says that experiments upon the rock about Monroe had already demonstrated its value for such purpose. Winchell in 1861 suggests that further tests be made upon the rock with a view to determining just what hydraulic properties it does possess. Some little experimentation has been carried on by private parties but no complete or conclusive tests have been yet applied. Edward Vorster, formerly of Monroe, now of New York City, conducted some experiments upon the Monroe stone which proved unsatisfactory, he thought because of the absence of sufficient soluble silica and the presence of too much magnesia. Magnesia, however, is perfectly hydraulic and when properly calcined will set under water and form a stony mass. Homer Wilcox, of Jackson, in a letter quoted above in § 2, makes the following statement concerning his tests upon the Ida dolomite:

> "From a series of experiments with rock from quarries one mile west of Ida Station, Monroe county, Michigan, I did not find the burned and ground rock a true hydraulic cement and yet it possessed properties different from any other rock I found in Monroe county, and I secured samples from, I think, all the quarries in that county. Ida limerock burned moderately hard, made a slow-slaking, slow setting lime when used as quicklime, but the same stone burned very hard lessened in bulk, became heavy and would not slake; but when ground into a flour and mixed with water set slower than the ordinary cements of the country (Akron or Louisville), and became ultimately harder than either Akron or Buffalo. I was, however, unable to calcine the rock hard enough in ordinary kilns to insure this result."

Hydraulic properties of perhaps a high order of excellence are suggested by these experiments. With specially constructed kilns and skilled labor in charge the rock might be made to produce a good quality of hydraulic cement.

The requirements for an hydraulic cement rock, according to Lord, are a limestone, magnesian or not, having intimately mixed with it 15 to 35 % of clay and a little potash or soda. Sand should not be present in the form of grit and the rock should dissolve in hot acid giving much muddy residue. Mr. Edward D. Boyer the Superintendent of the Hercules Cement Co. of Catasauqua, Pa., has kindly supplied the following average analysis of their rock, which, he says, is practically the same for the entire now famous Lehigh region.

Calcium carbonate	69.375
Silica	14.280
Alumina	9.000
Iron	2.810
Magnesium carbonate	2.353
Potash salts, moisture	2.182
	100.000

A table of American cement rocks was published in Vol. VI of the Ohio Geological Survey which may be of value in this connection for reference. The proportions of the various constituents are seen to vary greatly. These rocks are burned with a bright red heat in suitable furnaces and then ground in mills to an impalpable powder.

TABLE XII.—COMPOSITION OF AMERICAN CEMENT ROCKS.

Locality.	Calcium carbonate.	Magnesium carbonate.	Silica.	Alumina.	Iron oxide.	Alkali.
Ulster Co., New York....	30 72	35.10	19.64	7.52	2.38	4.10
Cumberland, Maryland...	41.80	8.60	24.74	16.74	6.30	6.18
New Lisbon, Ohio........	69.00	3.40	15.65	6.80	2.50	....
La Salle, Illinois..........	42.25	31.98	....	22.18	....	....
Bellaire, Ohio............	46.52	26.40	16.41	5.44	3.38	....

The composition of the rock has to be carefully watched in order to determine the amount of burning required and the grinding needs the same careful supervision. So far as analyses have been made of the Monroe rocks there are none of them which show a composition which would promise much in this direction. There is too much silica of the insoluble variety in many of the beds and in none of them does there seem to be sufficient alumina.

In the manufacture of Portland cement the proper proportions of clay and calcium carbonate are artifically united and burned at a temperature of 2,900° F. During this burning calcium silicate, and calcium aluminate are formed (the former below 1300° the latter above), which upon being ground and then wet, become hydrated, harden even out of contact with air and form insoluble masses. These cements do not slake as does lime and do not require any carbon dioxide gas from the air in order to harden. The celebrated English cements are made from the chalk beds and clay dug from the ancient bed of the Thames and Medway rivers. Analyses of these cements show the following range in composition, according to Heath.*

Lime	58 to 66%
Silica	20 to 26%
Alumina	2.5 to 10%
Potash	1 to 3%
Soda	0 to 2%

A mixture that ordinarily suffices to secure the proper composition is 72 to 77% of calcium carbonate and 23 to 28% of clay. The carbonate may be in the form of limestone or of marl and should be quite free from magnesia and sand. The clay should be of an even grade and free from grit. When rubbed between the fingers it should have a smooth greasy feel and should not stain the fingers. Silica in combination with potash and soda is spoken of as *soluble* and must be present in the clay. Too much iron and gypsum are objectionable; of the latter from one to two per cent may be tolerated. Caustic magnesia (MgO) forms a hydrate and sets with great hardness. When it and caustic lime (CaO) are present in uncombined form in the cement, however, the lime sets first and the magnesia later thus causing injury if the percentage reaches 4 to 5 per cent. Magnesia may be made to combine with silica and alumina as in the case of the lime but the hydration of its compounds is also slower than those of calcium. In order to show the composition of some of the mixtures from which English Portlands are made the following table is reproduced from Redgrave.†

TABLE XIV.—COMPOSITION OF ENGLISH PORTLAND CEMENTS.

Ingredients.	Folkestone, chalk and clay.	Forest of Dean, limestone and clay.	Barrow Lias, quarry mixture.
Sand	2.50	5.57	2.58
Silica	11.83	9.61	11.41
Ferric oxide	1.97	2.42	2.34
Alumina	5.23	3.45	4.80
Iron pyrite	Trace.	....	.43
Calcium carbonate	74.18	75.89	74.09
Magnesium carbonate	1.29	1.50	2.61
Calcium sulphate	.18	.16	.21
Potash	.90	.88	.93
Soda	.31	.39	.46
Water	1.82	.61	.43
	100.21	100.48	100.29

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*A Manual of Lime and Cement. 1893. p. 42.

†Calcareous Cements, their Nature and Uses, p. 45.

Mr. Homer Wilcox in his tests of Monroe rock added alumina to the Ida dolomite thus preparing a Portland type of cement. In his letter he gives the following statement of his results.

> "I made mixtures of this Ida quarry rock in varying proportions with clay from various sections of Michigan and some from other states, but found no practical results, except in case of one particular kind of clay obtained from the coal mines of Jackson county, Michigan. I ground Ida quarry rock into flour without burning and mixed it with clay from the coal strata at Jackson, about ¼ clay and ¾ rock. Let it dry into soft bricks after mixing—then burned. It became very hard and slightly vitrified. This product I ground after burning and it was a pure hydraulic cement and the specimens from it superior in firmness, heft and hardness to any Portland cement I ever used, whether made in the United States, England or Germany. It cost too much, however, to manufacture for market and I abandoned the intention to place it on the market for that reason. I tried the same clay with limerock from other sections of Monroe county, but did not obtain the same results."

It is to be expected that the high percentage of magnesia in the dolomites of the Monroe series would prevent their use for such cements. In the quarries upon the Macon, however, as pointed out in preceding sections, limestone of sufficiently high grade occurs. The bed of marl south of Monroe (§ 11 of this chapter), is suitable also for this purpose but not enough of it is in sight. The clay deposits which constitute the till are too stony and sandy for use with the carbonate. The most promising deposits are in the southeastern parts of the county, Erie, La Salle and Monroe townships, where clay sediments from the glacial lakes occur most abundantly. These deposits are freest from pebbles and have a relatively small percentage of sand.

§ 6. Road metal.

The nature of the soils and the flat slopes conspire to give Monroe county exceptionally poor roads. In certain sections the roads are practically impassable for any kind of conveyance for several weeks of the year. Aside from the mere convenience and pleasure of the residents good roads are sadly needed in order that crops and farm supplies may be more economically transported. The economy arises from the saving in time, horseflesh, wagons and harness and the fact that crops may be marketed when the price is most advantageous, rather than simply when the highway permits. With a system of hard roads much of the necessary farm teaming may be done when the clay soils adjoining are not fit for cultivation and thus the time of the farmer, his hired help and team disposed to better advantage. Three tons may be drawn upon a good road with greater ease and less expense than one ton upon a poor road. Some 10,000 representative farmers from all parts of our country were called upon for estimates as to the cost per mile of hauling one ton of produce to market. The average cost for the entire country was 25 cents while in certain sections of New Jersey where the roads have been improved by a system of state aid the estimates averaged from seven to ten cents, making a saving of from 15 to 18 cents to the mile for each ton of produce.* In consequence of this saving there is at once an increased valuation in all property that secures the full benefit of improved roads. In the neighboring state of Indiana some 40 to 50 representative farmers who have lived under a system of poor and later of good roads have estimated that the increase in the market value of their land is $6.48 per acre, which is believed to be a very conservative estimate. But even this low estimate would mean an increase of $4,147.20 for each section of land. The total estimated annual loss from poor roads for a hundred acre farm is given by the U. S. Bureau of Agriculture† as $76.28, or a little less than $500 annually for each section. This loss alone in six years would construct and maintain an excellent stone road past every farm house in the county. In the Circular No. 28 above referred to, Director Roy Stone of the Office of Road Inquiry, quotes a Canandaigua farmer, whom he had questioned concerning his extra taxes as saying, "In this one week, by the advantage of having these stone roads and getting to market with my hay when it sells at a good price, my teams have earned $5.00 every day, while my neighbors' teams on the other roads are eating their heads off. We could not afford not to have these roads; we do not care anything about the taxation."

There are no available deposits of gravel in the county such as occur in Lenawee and Washtenaw counties, but Nature has given Monroe inexhaustible supplies of still better road metal and distributed it so that it is fairly accessible from all parts of the county. When the dolomites and limestones are crushed and spread over a road bed, which is properly drained, the surfaces of the stone become firmly welded and a very solid foundation results. It is not necessary to treat the entire road with crushed stone but simply one-half of it leaving a dirt road alongside, which at certain times is as satisfactory for driving as the compacted stone. This reduces the expense of construction and maintenance very considerably and is now being tried about Canandaigua, New York, with gratifying results. The stone used there are common field boulders which are drawn

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*Circular No. 28, U. S. Dept. of Agriculture, Office of Road Inquiry.
†Circular No. 23.

from the land by the farmers at a good price per load, thus ridding the land of a serious incumbrance. Those of a single region are heaped together at a convenient spot and finally broken up by a portable crusher owned and operated by the township. The crushed stone are then distributed by local teams.

An excavation from 10 to 12 inches deep and 8 feet wide is made to receive the stone. Experiments, however, have shown that a six inch layer is satisfactory for ordinary roads, although 9 to 10 inches would probably be found more economical in the end. This thicker bed would require about 1300 cubic yards of crushed stone to the mile, which at the Monroe crusher would cost, at present prices, $780. The cost of transportation, preparation of the bed and spreading of the stone would have to be added. In some sections of the county the railroads are willing to carry road materials at the cost of transportation for the sake of encouraging improvements. In one sense every such road constructed is but an extension of the railroad to the farmers' residence. As the roads are ordinarily laid out it would be necessary for each section to become responsible only for two miles of road in order to completely cover the county. At first, however, only a few roads radiating from the main centers would suffice and these could be located with reference to the individual assistance that residents along the routes would be willing to render. Undoubtedly the expense of road construction could be very materially reduced by having each township, or adjoining townships, own and operate portable crushers. In 1896 such a crusher was worked by private parties in the eastern part of Whiteford township. A temporary tramway was laid and the stone were used in constructing one of the excellent roads leading out of Toledo. In only a few localities in the county are field stone abundant enough for such use. If the amount of time and labor that is ordinarily expended in improving (?) the roads could be more wisely directed great good would result.

Four permanent crushers have been constructed and operated in the county but two have ceased working. One of these was located alongside the Michigan Central just south of Newport Center and the other on Plum Creek at the quarry of the Detroit Stone and Supply Co. Those still in operation are at Woolmith and at the quarry of the Monroe Stone Co. north of Monroe. At Woolmith there are some beds capable of yielding a good quality of rock for macadamizing purposes, but the bulk of the rock possesses so much sand that it more readily crumbles and probably does not bind its fragments together so firmly. A more even type of dolomite is being crushed north of Monroe, the quarry having been operated almost continuously since Sept. 1, 1895. (See Plate IV.) The market is principally Detroit, but shipments are made to Saginaw, Bay City, Jackson, Adrian, Toledo, etc., the quarry being favorably located with reference to the Lake Shore, Michigan Central and Pere Marquette roads. During the season of 1899 this company shipped 55,706 tons at an average price of 60 cents per ton. Three grades of stone are supplied ranging from ½ to 2½ inches in diameter. The "Screenings" are used for cement sidewalks and are sold at twenty cents per ton.

As reported to the United States Geological Survey the total value of the limestones and dolomites marketed in Monroe county during the year 1897 was $29,812; for 1898 it equaled $23,779 and in 1899 was $43,183.

§ 7. Glass sand rock.

The bed of Sylvania sandstone has been described in considerable detail in Chapter III, § 6. It is so friable that it has no value for building purposes, although blocks firm enough for foundations have been taken from the Raisin bed. The chief use of this remarkably pure bed is the manufacture of glass, for which its fine even grain and purity well adapt it. It had been tested for this purpose before Michigan became a state and attention was especially called to the bed by Hubbard, Winchell and Rominger in their state reports. The outcrop was originally preëmpted from the government by Col. Thomas Caldwell, a British officer, and held by him and his heirs for many years. Charles Toll of Monroe has owned 60 acres of this land for over 40 years and for some time back has held sand and mineral rights on 150 acres adjoining. From 1860 until about 1873 or 4 the pits were operated by Toll, the sand being washed and sifted and shipped to Bridgeport, Bellaire and Benwood, Ohio; to Pittsburg, Wheeling, Rochester, Syracuse and Hamilton, Ontario. The sand was said to have been removed to a depth of twenty to twenty-five feet. The sand had to be teamed seven miles over a sand road and this so greatly increased the expense that it was finally unable to compete with beds more favorably located. The sand has been found to mix intimately with the fusible bases so that it melts rapidly and yields a glass free from color. Recently this land of Toll and his mineral rights have been leased by the Michigan White Sand Company, with headquarters at Maybee, Michigan. (W. H. Cowles, President and F. G. Strong, Secretary.) This company has put up a small experimental plant, in which the sand is heated to 400° F. without washing and then sifted, thus securing several grades of purity and fineness. A larger plant is contemplated which will have a capacity of 150 to 200 tons daily. The sand when washed gives no iron, traces only of calcium and magnesium carbonate and 99.59% of silica, thus showing very superior qualities for higher grades of glass. The whitest sand is said to be reached at a depth of two feet in the bed. By following the bed in the direction of the dip, as well as laterally the quantity is practically unlimited. Proceeding northwestward a capping of dolomite would soon be reached which would form a good roof in case it was desirable to mine the sand. The bed will be found to drop at about the rate of 25 feet to the mile.

The organic stain found in the upper part of the bed at the outcrop would be expected to disappear beneath the clay and dolomite. The course of the sandstone across the county is shown upon Plate I from which it is readily seen just where it is crossed by the various lines of railroads. A further examination of Plate XV will show the approximate thickness of the drift at each locality in case it might be desired to get to the sandstone by sinking a shaft through the drift. It should be noted that the full thickness of the bed would be obtained only by striking it on the western or northern edge of the belt. In case a test shaft happened to first strike the dolomite, the sand would be found just beneath and the dolomite would serve as a roof. As a rule the bed yields water in abundance and in mining the sand this water would have to be bargained with. It is not improbable that this water which it would be necessary to pump from any opening made into the bed would be quite sufficient for washing the sand. This sand has had several minor uses for which it is well adapted on account of its whiteness and sharp cutting edges. It makes a beautiful painters' sand, is very popular with the Diamond Match Company for use upon their match boxes and is unexcelled for scouring purposes, for which it is used locally. Soap charged with this sand would probably rival "Sapolio" for rough cleaning.

§ 8. Brick and tile.

The manufacture of brick upon a small scale was begun at a very early day to supply local demands. At the time of the Houghton Survey, Frenchtown had produced a total of 1,600,000. One kiln had been burned at Brest and about 100,000 at Newport. A trial had been made at Dundee and abandoned on account of the calcareous nature of the clay. Good brick were said to have been made in London township from clay obtained from the Saline valley. No statistics relating to the gradual development of the clay industry in the county are available. In 1896 the total value of the clay products was $15,720 and for 1897, $12,410. During the season of 1898 there were manufactured in the county, 2,112,100 brick, valued at $10,535 and tile valued at $12,470, making a total of $23,005. For 1899 there were burned 1,625,000 brick and 1,165,000 tile, having an approximate total value of $23,000. The position of the eight factories now in operation is shown on Plate XV. In 1896, at the time of the first inspection of the county for this report, two others were operating, one at Dundee and the other at Erie.

Notwithstanding the inexhaustible supplies of clay within the county, owing to its method of formation and accumulation, it is so charged with pebbles, many of them calcareous, as to be worthless for brick and tile. Upon burning, the fragments of carbonate are converted into lime, which will eventually slake and ruin the article containing them. Mechanically also they injure the soft brick and tile as they are forced through the die. This difficulty is in part obviated by running the clay first through a "crusher," which reduces the pebbles to coarse sand. From the till clays of various texture and purity could be obtained by a process of washing, but the time is not at hand when this would be profitable for ordinary use. Nature has, however, done considerable of this and deposited a washed product along the river valleys from which a good grade of brick and tile may be manufactured. Such clays usually contain sufficient sand to prevent warping and shrinkage in the process of burning. The sites of former lakes frequently contain clay of a very homogeneous character, which was washed in from the surrounding region. Such beds are generally only from one to three feet thick and in many cases underlie layers of muck and marl. This action took place upon a much larger scale in the case of the great glacial lakes described in Chapter VI, so that in the eastern, and particularly the southeastern corner of the county the superficial clays are to a greater or less extent utilizable. Whatever the color of the clay it burns in all cases to a cherry red, owing to the conversion of the iron compounds into the red oxide (Fe_2O_3).

The old method of moulding brick by hand has been discarded, but a near approach to it is still found in the "soft mud process," used at Monroe. The clay is brought into a soft, pasty condition by the use of water and kneading machinery, and then forced into sets of moulds, similar to those formerly used in the hand process. These moulds are emptied and resanded by hand, the bricks being spread in the yard to dry, where they are liable to be injured by the weather. Such brick are open grained and porous, but do not show the cracks about the edges and corners which so frequently occur in brick forced through a die. In the "stiff mud process," which is the one very generally employed, the clay is moistened sufficiently to become plastic but is at all times stiff enough to hold its shape. There being less water to be gotten rid of the drying takes place under long sheds. The stiff clay is forced by means of an auger or plunger intermittently from the machine through the openings in a steel plate. These openings are of suitable size and shape to give the clay its desired form and it is then cut into proper lengths, during a period of halt, by a frame carrying tightly stretched wires. Bricks made by this process are more compact, have a smoother surface and are stronger, but quite generally show cracks along the edges and other imperfections, due to the action of the die and the imprisoned air. Most of the kilns used in burning the brick and the tile are of the "up-draft" pattern but there are a few "down-draft" kilns in operation. In this type of kiln the heated air is admitted at the top and is compelled to pass downward before it can escape, thus giving a much more even burning to the brick and tile. The following data relating to the factories were collected in September, 1899:

Milan Brick and Tile Manufactory, owned by the Farmers and Mechanics Bank of Milan, H. S. Knight, Manager. Located alongside of the Wabash railroad, N. E. ¼, S. W. ¼, Sec. 2, Milan township, within one-fifth mile of the Ann Arbor road. The clay for tile is of a bluish variety obtained from the Macon Creek in N. W. ¼. Sec. 14, place of Warren Lewis; from 6 to 10 inches of muck have to be removed. Six feet of clay may be worked before it becomes stony. The brick clay is obtained from the Saline, Sec. 1, Milan, place of O. W. Leonard, and is of a yellow color and sandy. Stiff mud process; Brewer machine, with a capacity of 20,000 brick and 8,000 tile daily. One double up-draft kiln. The engine used is 25 horse power and about 20 hands are employed. During the season of 1898 the company manufactured 100.000 brick and 120,000 tile; in 1899 about 280.000 brick and 125,000 tile. The markets are mostly local, but shipments are made along the railroads as far as Toledo and Detroit.

Meyers Bros., Azalia. Ann Arbor railroad. Clay is obtained from bed of the North Branch of the Macon and is a mixture of blue and yellow as worked. From four to six inches of muck are first removed, below which is 1½ feet of blue clay and still lower 3 to 6 feet of yellow before a bed of gravel is struck. The factory has been in operation 6 years, and employs about 14 hands. A Brewer machine is used, driven with a 35 horse-power engine, capacity 12.000 of 3 inch tile and 24,000 brick; down-draft kiln. Markets are local and shipments to various points in Monroe and Washtenaw Counties. Tile are made from 2½ to 8 inch. During 1898 there were put out 225.000 brick and 220,000 tile; during 1899 from 250,000 to 275,000 brick and about 250.000 tile.

Charles Jacobs, S. W. ¼, S. W. ¼, Sec. 34, Summerfield. The clay is a local deposit found just north of the factory. There are 6 to 7 inches of muck and loam, beneath which lies 2½ feet of streaked blue and yellow clay, before clay carrying pebbles is reached. This plant was operated for several years by Wadsworth and Harwick. The machine used is a Brewer with a capacity daily of 15,000 3 inch tile and 15,000 brick. Markets are entirely local as there are no shipping facilities. During the season of 1899 there were manufactured here about 45,000 brick and 300,000 tile. Down draft kiln.

Mrs. Katharine Stout, Ottawa Lake. Charles Jewell, foreman. A streaked yellow clay is used obtained near at hand, carrying some pebbles. Stiff mud process; Adrian machine, No. 2; steam power. One down draft kiln in repair. Only tile are made here and mostly 3, 4 and 6 inch; but ranging from 2½ to 10 inches. Capacity of machine is 6,500 of 3 inch. During 1898 there were burned 200,000 tile and about 100,000 in 1899. The factory is near the Adrian-Toledo branch of the Lake Shore and shipments are made as far as Toledo.

August G. Matthes, Strasburg. Adrian-Monroe branch of the Lake Shore R. R. Clay used is a blue and yellow streaked bed three feet thick, beneath which is 6 to 8 feet of blue clay (till). Clay is somewhat stony but not sufficiently so to cause serious trouble. Machine is an Adrian, No. 2, stiff mud process. Capacity daily 14,000 brick and 13,000 3 inch tile. Employs 7 to 8 hands. One up draft kiln. Last season Mr. Matthes made 250,000 tile and 150,000 brick and in 1898 200,000 tile and 125,000 brick. Markets are entirely local. Brick sell for $4.50 to $6.00 per thousand in the yard. The following prices per thousand are secured for tile: 3 inch $9, 3½ inch $12, 4 inch $14, 5 inch $17, 6 inch $25, 7 inch $35, and 8 inch $40.

Robert C. Herkimer, N. E. ¼, S. E. ¼, Sec. 18, Exeter. Operated by Frederick Linenfelser. Clay used is of the yellow variety and obtained from the Saline flats. Brewer "6 A" machine; capacity 25,000 brick and 12,000 3 inch tile. Engine 25 horse-power; six hands; one up draft kiln. In 1898 there were burned here 150,000 brick and 140,000 tile; in 1899 about 250,000 brick and 60,000 tile. The markets are purely local. Tile of the 3 to 4 inch size are mostly made, but range from 2½ to 8 inch. The prices are about the same as those above given for the Strasburg factory.

John Strong and Sons, South Rockwood, Michigan Central railroad. Clay obtained from surface near plant, bluish-yellow. The sod only is stripped off from the bed, five feet of which are usable. The pebbles present are first crushed. Adrian machine; stiff mud process for tile, soft mud process for brick. Engine 50 horse-power; daily capacity 30,000 brick and 10,000 to 12,000 3 inch tile. Two stacks for brick and two down draft kilns. 13 to 14 hands employed. During season of 1898 400,000 brick and 250,000 tile were made, but owing to overstocking none were burned in 1899. Markets are local, to points in Monroe and Wayne counties and north of Detroit. Tile from 2½ inch to 8 inch are made, but the demand is chiefly for 3 and 4 inch. The prices are for 2½ inch $8, 3 inch $9, 4 inch $13 and $6 for brick.

Charles G. Eaton, Monroe. Pere Marquette R. R. and Adrian-Toledo branch of the Lake Shore railroad. A yellow stony clay is used from a local deposit. A crusher removes the coarser pebbles and crushes the smaller. Soft mud process for brick. The bed of clay used is 3¼ feet thick, from which only the surface has to be stripped. Sand has to be added to the clay. Brewer machine is used, with a 25 horse-power engine, capacity 30,000 brick daily. About 20 hands are employed. Up draft kiln for tile. Sizes range from 2¼ to 8 inch, with most of 3 to 4 inch. In 1898 about 640,000 brick were burned and about 80,000 tile; in 1899 about the same amount of brick and about 65,000 tile. Markets local at about the same prices as above quoted.

§ 9. Natural gas and oil.

Covering the northwestern part of Monroe county as shown upon Plate XV there is an area over which there are strong surface indications of oil and natural combustible gas. This area covers Milan, London, Dundee, western Raisinville, nearly all of Summerfield and the northwestern corner of Ida townships. The oil impregnates the rocks and forms a scum over the water of ponds, streams and wells, giving it sometimes a very offensive odor. The gas bubbles up through the water, sometimes as a continuous stream, usually only as occasional bubbles. Still more of it escapes into the air without being noticed. Where especially abundant in wells it burns upon being ignited, giving a hot but only slightly luminous flame. It has comparatively little odor, by which it may easily be distinguished from the offensive, hydrogen sulphide gas (H_2S) which is found in wells, imparting to the water the odor of "rotten eggs." From carbon dioxide gas which may also occur in wells and springs it is distinguished by its combustibility, since this former gas not only will not burn but will not support combustion. As pointed out in Chapter II this gas and oil are more directly associated with the St. Clair, Traverse and Dundee formations and are most abundant in Milan and London townships. This is known as surface or shale gas, can have no great volume and rarely ever any great pressure. It does not occur at definite horizons, is not associated with oil, salt water or any definite rock structure. The gas obtained from the drift deposits, in all probability, is derived from the underlying rock formations. The only practical use for this gas is for domestic purposes for which it has been but little utilized in the region. Piped into the house and used economically it would last for a number of years, when a new well could be sunk at but little expense and a new supply obtained. This should be looked upon as one of the resources of the farm and should be as carefully husbanded. The gas is not as valuable for illuminating as for heating purposes owing to its lack of luminosity. An Ohio man has discovered that if the fire brick of the grate are occasionally sprinkled with salt a more luminous flame may be secured.*

There is no necessary connection between this surface gas and oil and the deeper seated deposits so eagerly sought for by means of deep borings, since both may have been separately produced. At Findlay, Ohio, however, before the wonderful discovery was made such surface indications had been known for many years. At ten different places in the county deep wells have been drilled at heavy expense with the hope that some such deposits would be discovered as those which have made northwestern Ohio famous. Six of these wells have penetrated the Trenton limestone, the productive horizon in Ohio, but without adequate returns. (For records see Chapter III § 8). From data thus obtained it is apparent now why these wells have failed and there can be no justification for further expenditure to secure oil and gas from the Trenton within the limits of Monroe county. The gas and oil fields of Ohio and western Ontario are located along the crest of the great Cincinnati anticline, an uplift in the Trenton and overlying strata. This upheaval began in Silurian times, but was arrested, and the final folding as determined by

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*In some districts of Ohio this "low pressure drift" gas has proved to be of commercial value. The use of Welsbach burners might remedy the lack of luminosity.

Foerste[*] took place in the late Devonian or early Carboniferous. As mapped by Orton[†] this anticline passes northward from Findlay to the east of Toledo, passing under Lake Erie and reappearing in Ontario. In a paper read in 1887 before the Royal Society of Canada.[‡] Robert Bell says:

> "There seems to be no doubt that the occurrence of petroleum in Enniskillen is connected with the Cincinnati anticlinal, but the writer, after having done a considerable amount of geological work in Western Canada at various times since 1859, and having carefully studied the question, has come to the conclusion that this anticlinal, coming up from Ohio, does not run eastward, as Logan supposed, into Lake Ontario, but that it maintains its northward course, and runs into the southern extremity of Lake Huron." * * * "Northward of Lake Erie, an impartial study of what is actually known of the geographical structure, as well as of the distribution of the formations, indicates that its axis, after crossing the lake, continues on, as we would naturally expect it would, in the same general north-northeastward direction bearing through the counties of Essex, Bothwell and Lambton, from about Littles' Point on Lake Erie, to about Kettle Point on Lake Huron."

From this quotation and the figures given in Chapter III, § 9 concerning the drop in the Trenton towards the north and west it will be apparent that Monroe county is unfortunately placed upon the western slope of this productive anticlinal. The higher portions are to the east and south and towards these directions the oil and gas have been drained. The most promising part of the county for a test well was theoretically in the southeastern corner since this is nearest the crest of the anticline. Of all the ten deep wells the one nearest this region has proven most productive. This well was begun in November, 1898, and completed December 10th. It is owned by F. C. Potter in the N. W. ¼, N.,W. ¼, Sec. 22, Erie township. The Trenton was struck at a depth of 1,555 feet, (see Chapter III, § 8), and entered 112 feet. The original gas pressure was 25 pounds to the square inch. It has been piped to the house and is used for lighting and cooking. The well contains oil and has been several times bailed out, some ten barrels having been thus secured in August, 1899. Most of the other wells have given some temporary showing, enough to raise the hopes of the stockholders, but none of them have done as well even as the Potter well. The three Monroe and the two Dundee wells have furnished decisive tests so far as the penetration of the Trenton is concerned. According to Orton, who followed very carefully the development in Ohio, the productive part of the Trenton is usually confined to the first 15 feet. In his report of 1888, [§] he says

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[*] American Geologist, Vol. VII, 1891, pp. 97 to 109.
[†] Ohio Geological Survey, Vol. VI, pp. 46 to 55.
[‡] Trans. Roy. Soc. of Can., 1887, p. 105.
[§] Geological Survey of Ohio, Vol. VI, p. 118.

"Thus far, unless some gas or oil is found in the uppermost sheets of the Trenton limestone, none is found below, and in but one case have valuable accessions to the supply been made more than fifty-five feet below the top of the rock. There are scores of instances now on record, all agreeing as to this point, and yet most of the wells that fail to find gas in the proper horizon are carried down 200, 300, 400 feet into the solid limestone before being finally abandoned. Such expenditures are a dead loss to the investors, and are generally of but little value to the drillers. The same perversity shows itself in multiplying wells after one or even after repeated failures in territory which must be counted on highly probable grounds as unproductive."

Gas and oil have had a common origin which is now generally believed to have been from the decomposition of organic matter, animal or vegetable, or both, which was originally deposited in the sedimentary rocks. There is a divergence of opinion as to whether the gas and oil were produced from the original partial decay of the organic matter at the time of its deposition, or later as a product of slow spontaneous distillation.* Probably the view that now receives widest acceptance is that these products have resulted from the decomposition of organic matter, at normal temperatures, either at the time the rocks were formed or later. The oil and gas may still be associated with the original beds in which it was formed or it may have escaped upward until its progress was arrested by impervious beds of suitable shape to confine it. In case no such beds existed it would escape to the surface and be lost. As might be expected from their method of formation limestones and shales would be the only beds with which any considerable amount of organic matter would be associated and in such beds oil and gas are believed to have originated. The organic matter of limestones was in the main of animal origin and gave rise to a dark heavy offensive oil containing a relatively large quantity of sulphur and nitrogen. It is oil of this nature that is found in Ohio and western Ontario. Oil derived from shale is in the main of vegetable origin and is lighter in color, contains less sulphur and nitrogen and has not the offensive odor of the limestone oils. Most of the oils of the Pennsylvania region are of this nature. Fissured limestones, sandstones and conglomerates serve as reservoirs for oil and gas, usually with an arched capping of shale. Where salt water, oil and gas all occur they are arranged in the order of their specific gravities; the gas would first be reached in the boring, would escape, give place to oil eventually and lastly to salt water. It is thus apparent why the crests of anticlines and of domes are so productive of oil and gas and why the slopes may prove barren, or yield a small quantity of oil or salt water only.

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*See Geol. Sur. of Mich., Vol. V, Pt. II, pp. xix to xxiv.

§ 10. Artesian water and mineral springs.

Three belts of artesian water strike across the county in a northeast and southwest direction,—an eastern, a central and a western belt. Within these areas, when the rock is penetrated a short distance, the water generally rises to the surface and flows, thus saving the expense of windmills and the trouble of pumping for stock and for irrigation. This water is very generally charged with compounds of calcium, magnesium, iron and sulphur, derived from the limestone, dolomite and shale through which it has passed. The iron and sulphur are derived largely from the decomposition of the pyrite and marcasite, which are very commonly present in these rocks. Hydrogen sulphide gas is produced which is readily absorbed by the water, to which it imparts the odor of "rotten eggs." Upon exposure to the air this gas is decomposed and the sulphur is precipitated as a white mealy precipitate over troughs, stones and vegetation. When in quantity and after standing it begins to assume a slight sulphur yellow color. The iron is present in the water mostly as a carbonate and upon standing it is oxidized and deposited as a yellowish brown coating over objects, this being the hydrated oxide. This is insoluble in water and is readily distinguished by its color from the sulphur. When both iron and sulphur are present in the water in the form described a chemical combination takes place and iron sulphide results, giving the water an inky black color. A number of wells of this character were met with in the county, although the water of a region usually contains one or the other of these substances alone. In some instances artesian water is derived directly from sand and gravel layers in the drift and is reported as soft.

Continued drought makes no perceptible impression upon many of these wells, while with others the flow may be reduced and almost or quite stopped. The opening of new wells has been found to affect the flow of others in the neighborhood and the areas over which artesian water may be secured are becoming more contracted. Wells which formerly flowed in the southern part of Erie township, back three miles from the lake, have now ceased although the water rises to near the surface. The opening of the Woolmith quarry in Exeter township had a noticeable effect upon the water in the wells to the northeast. The deep well in the eastern part of the city of Monroe so seriously interfered with the action of the wells of that region that it had to be plugged. At the place of Nelson Richards, S. E. ¼

S. E. ¼, Sec. 1, Exeter, a flowing well ceased to act when another was started at Welsey Richards' place, one-half mile west, but by compelling the latter to rise four feet above the surface both wells flow. Meteorological conditions are found to affect the wells in several very noticeable respects, more or less puzzling to their owners. These effects may be thus summarized:

William Young, N. W. ¼, S. W. ¼, Sec. 6, Milan. Gives a muddy deposit before a storm.

J. R. Vescelius, S. E. ¼, N. W. ¼, Sec. 6, Milan. Becomes roily before a storm.

Charles Campbell, S. E. ¼, S. E. ¼, Sec. 27, Milan. Water becomes roily when wind is in the southwest.

Brightbill Bros., S. E. ¼, S. E. ¼, Sec. 3, Exeter. Three to four hours before a storm gives a black sediment.

William Laurie, S. W. ¼, N. W. ¼, Sec. 6, Ash. Water gives a black deposit 12 to 14 hours before a storm.

Scofield, Exeter. Level of water in well said to be raised three feet by an east wind.

T. M. Taft, S. W. ¼, N. E. ¼, Sec. 7, Summerfield. Water stands higher with an east wind, lower with a west.

G. W. Dauncey, S. E. ¼, N. W. ¼, Sec. 7, Berlin. Water flows faster before a storm, but is not roily.

Charles Todd, S. E. ¼, N. E. ¼, Sec. 7, Berlin. Flowing well had nearly ceased to flow on account of clogging with sand but once just before a storm it broke out afresh and gushed with such noise as to be heard some little distance, throwing out much sand.

These phenomena may all be simply explained by the meteorological conditions that prevail before and during times of storm. The density of the air at such a time is reduced over the surface of the earth, so that its pressure on the column of water in the well is less. Air enclosed in the subterranean passages of the rocks is temporarily more condensed than that over the surface and its pressure upon the underground water, added to the regular hydrostatic pressure, causes the water to rise to a higher level, or to flow with greater force than usual. If sediment of any kind has been deposited in the underground channels the increased velocity of the flow will cause this to be again taken into suspension and the water becomes roily. The only supposable connection between the east wind and the height of the water in the wells is that the wind in this quarter frequently presages a storm.

The most western artesian area covers nearly the northwestern half of Milan township to the west of the Arkona Beach. It is a portion of a belt which extends from Lenawee county northeastward into Washtenaw. The artesian water is derived from the rock and from layers of the drift, which varies in thickness from 100 to 150 feet. Throughout this entire area the water does not always flow, lacking nine feet of reaching the surface in Milan village. The water rises from a few inches above the surface to 14 feet at Thomas Welsh's. Here one well at the barn rises higher and yields softer and warmer water than another at the house, near at hand. At the place of John Dennison, S. E. ¼, N. E. ¼, Sec. 20, a flowing well can be readily obtained anywhere by penetrating a bed of coarse gravel at a depth of 30 feet. The amount of water supplied by these wells is never large, the best of them simply filling a one inch pipe. The heaviest flow of the region is obtained from the crest of the Belmore Beach, one mile over in Lenawee county at the residence of James Harmon. A strong flow was secured from a depth of 48 feet, rising 9 feet above the surface. A 1½ inch pipe is filled and the water is used in the dairy. At the barn a similar well was struck and plugged because of the difficulty in disposing of the water. This water is impregnated with iron.

The middle belt referred to consists of three detached patches extending in a northeast direction across the county. The most southerly is a narrow area about three miles long by one-half mile wide in Bedford township, just east of Lambertville. Some fairly strong flows are obtained in this region but they rise but little above the surface. In the central part of the county there is a large irregular area over which flowing wells may be ordinarily secured (see Plate XV). The water contains sulphur commonly when it comes from the rock but sometimes iron. The highest rise noted is 5 to 6 feet upon claim 472, South River Raisin.

The most northern area of this belt occurs in northwestern Exeter and northwestern Ash and continues as a narrow belt northeastward into Wayne county for a considerable distance. This region contains considerable sulphur at times in combination with iron. Some of the wells proved so offensive and so injurious to the soil that they were plugged. A rise of three feet above the surface is above the average.

The eastern artesian belt lies near the lake shore and consists of four detached areas, one small one in eastern Erie, a second about the mouth of the Raisin and extending southwestward into Erie, a third in eastern Berlin and a fourth irregular one in northwestern Berlin and eastern Ash. In Brownstown of Wayne county the two latter areas unite and continue towards Detroit along the Detroit River. As might be expected the flow of water is stronger in these regions and the rise above the surface is higher. At the Greening Brothers' nurseries south of Monroe the water reaches the surface with force enough to run sprinklers and when compelled to do so will rise 12 feet. Eastward at Lake Erie at the Lotus House there are two flowing wells which will rise 20 feet above the surface or 25 feet above the lake. The water of the wells in this lake region is generally charged either with sulphur or iron, seldom containing both in such quantity as to become dark. The heaviest flow of artesian water known in this part of the state was struck in September, 1899, upon the south bank of Otter Creek, about 2½ miles southeast of La Salle, at the residence of Edward Sharkey. The well is 51 feet deep and 6 to 8 feet in the rock, having been drilled with a three inch drill. September 4th water was struck and began to flow, slowly at first and then with greater strength. A wooden

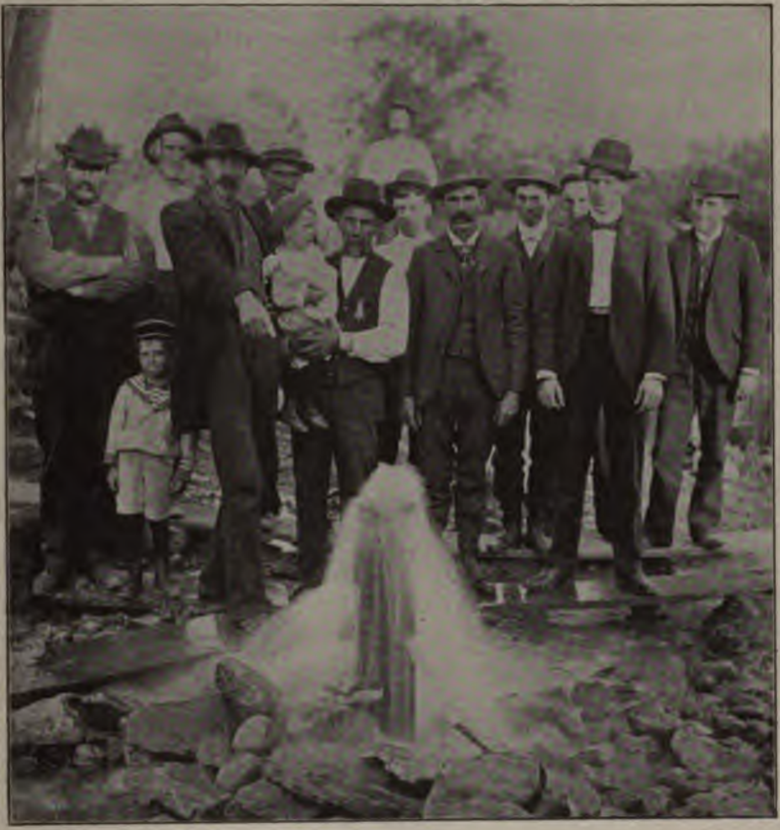

Fig. 7. Gushing well struck upon Otter Creek, September, 1899. Residence of Edward Sharkey, 2½ miles southeast of LaSalle.

pump-stock was driven into the hole and projected four feet above ground. Through this the water was thrown with force and to a considerable distance, latterly through 10 one and one-half inch holes bored in the side. Thus prevented from escaping freely the water began to rise through the clay around the mouth of the well and at a distance of 25 to 30 feet from it, forming a shallow lake about 100 feet across. By this time Mr. Sharkey became alarmed for the safety of his house and the pump-stock was withdrawn, an eight inch pipe being inserted in its place. At the time of the writer's visit a very rapid stream two feet broad and four inches deep was flowing from the well to Otter Creek. Fig. 7 shows the well as it appeared September 16, 1899, as taken by an amateur.

Within these artesian areas not infrequently natural openings have been made to the surface through which the water escapes and flows as a mineral spring. These are more common in the central and eastern part of the county, back from the river to a distance of two to three miles. Some of them sometimes occur outside of the artesian areas, for instance the sulphur springs near the foot of Ottawa Lake upon the farms of Harmon Branch and William Bell. A strong natural flow of sulphur water, with some iron, occurs at Christopher Nichols' claim 685, South River Raisin. This would fill a five inch pipe and is but slightly affected by drought, never drying up. Upon land belonging to Catherine Sorter, claim 673, South River Raisin, there is a strong sulphur spring which feeds Sulphur Creek. This has been known to stop flowing but twice, in 1875 and 1895. South of Monroe 1¾ miles is located the somewhat celebrated "Shawnee Spring," upon claim 160, South River Raisin, just east of the Michigan Central tracks. From 1860 to 1879 or 80 the place secured some note as a resort. The water is said to retain practically the same temperature throughout the year and to be unaffected by drought. An examination of the water was made in 1864 by Prof. S. H. Douglass, then of the University of Michigan, who reported that the water contained free carbonic acid, magnesia, and abundance of lime, chlorides and sulphates and that hydrogen sulphide would probably be found in the water at the spring. The spring has formed a large mound of sphagnum moss and calcareous tufa over 500 feet across and 8 to 10 feet high, through which the water escapes by numerous mouths. (See Plate XVI.) Quite large masses of this tufa are loose in the field and ledges of it occur in position. The

SITE OF SHAWNEE SPRING NEAR MONROE. MOUND IS POORLY SHOWN.

water tastes and smells of hydrogen sulphide and is depositing sulphur. Similar springs with mounds of tufa are found to the south, upon lands of Mrs. Adeline Q. Navarre and Joseph Asam.

A large sulphur spring occurs upon the place of Peter Cushino, Otter Creek, near the Sharkey well just described. This has an elliptical basin 45 by 90 feet, with a 10 foot margin richly covered with *Chara*. The stream from the spring is not rapid, is 2½ feet broad and 10 inches deep. A similar but much larger spring occurs in the Erie marsh near Vienna, N. E. ¼, Sec. 22. It is reached by boat by punting one-half mile through an artificial channel. At a distance the site of the spring is marked by a spot of the most livid green contrasting strangely with the dark waters of the marsh. The general form of the spring is circular as shown in Fig. 8 and its diameter is about 160 feet. The bottom is funnel-shaped, a marginal strip of 25 to 40 feet shelving off slowly and then making a sudden drop. The bottom where visible through the clear water is covered with a mat of *Chara*, encrusted with a deposit of sulphur. The sounding line struck bottom at 30 to 33 feet, although it is quite probable that fissures occur leading to greater depths. The outlet from the spring is a small sized river having considerable velocity, a breadth of 33 feet and a depth of one to two feet. The current is so swift that there is some difficulty experienced in entering the

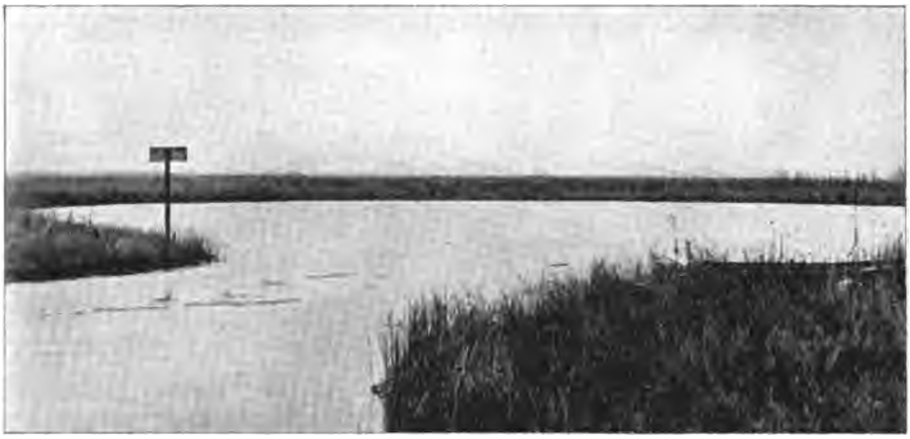

Fig. 8. Great sulphur spring in the lake marsh near Erie. The figure gives also a view of the inundated margin; cf. Fig. 5.

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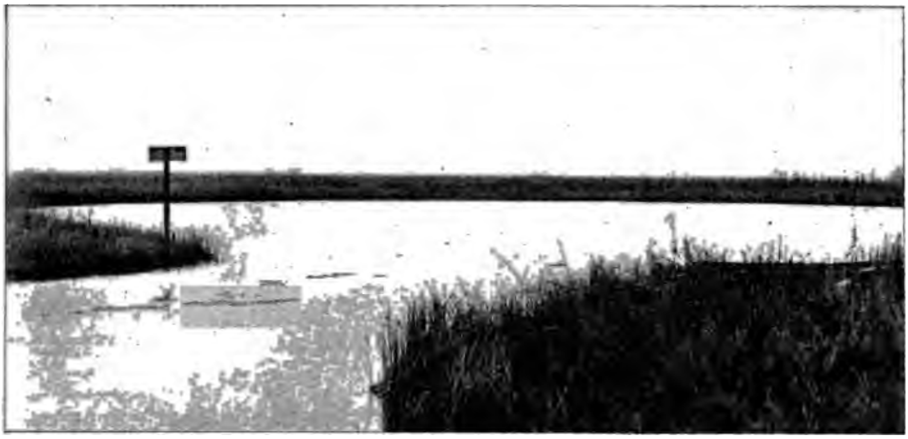

Fig. 8. Great sulphur spring in the lake marsh near Erie. The figure gives also a view of the inundated margin: cf. Fig. 5.

spring with a boat. The channel soon becomes broader and proportionately more shallow, and over the bottom of it much sulphur has been deposited. Fragments of tufa are found about the margin of the spring showing that the water is probably rich in calcium carbonate. It is very probable that these springs and flowing wells are fed by the water which enters the rocks in the western part of the county.

§ 11. Marl.

No extensive beds of this substance, for which the Portland cement industry has created a demand, are known to occur in the county. The largest deposit known occurs upon the property of Joseph Asam, claim 422, north of Plaisance Creek. Over an area of 6 to 8 acres there is a layer of black spongy muck containing many dead shells of *Helix*. Beneath this is found a bed of marl varying in thickness from one to three feet. The marl is so free from grit that, after washing, it has been found to produce a good polishing powder for gold, silver, nickel, brass etc. It was boxed and sold for this purpose some twelve years ago under the name Paragon Polishing Powder, being prepared by the La Plaisance Manufacturing Co. The marl contains some shells but appears to have been in the main precipitated from the water of a small lake charged with lime carbonate. Such a deposit may now be seen in process of formation over the bottoms of the series of lakes through which the Huron River flows in Washtenaw county. Upon claim 161, about one mile west of the Asam deposit at the place of Eli P. Duval, there is said to be a black deposit with white clay. The latter is undoubtedly marl and a similar reference to a 10 inch layer of "whitish dirt" was obtained at W. J. Kelley's, claim 520, South Otter Creek, where it is overlain by 2½ feet of yellow sand and one foot of black sand. Beneath the sand layer is one foot of yellowish-white clay, 1½ inches of gravel and then common clay to the rock. Judging from these deposits we have here a former lake site. At the cranberry marsh belonging to Clayton Everett, of Toledo (S. E. ¼, Sec. 24, Summerfield, see p. 157), more or less marl occurs, but the maximum thickness is said to be but 6 to 8 inches. It is quite probable that thicker deposits occur towards the center of the marsh, possibly of considerable extent. In his early report Hubbard reported marl as occurring on Sec. 7 of Exeter and Sec. 9 of Ash townships.* A very extensive marsh occurs in Sec. 9 of London and probably contains marl beneath the surface. It might be possible to dredge out here both marl and a suitable variety of clay for Portland cement. The clay would be found beneath the marl if both occur. Such use is the main one for this loose variety of lime carbonate. Its value as a fertilizer and for neutralizing the acidity of muck has been referred to in the previous chapter, p. 172. In the early days it was sometimes converted into lime by heaping it up into a pile and keeping a wood fire going around and over it until the carbon dioxide gas was driven off sufficiently.

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*Second Annual Report of State Geologist, 1839, H. R. No. 23, p. 110.

§ 12. Salt.

Springs along the Saline River furnished a weak brine for the use of the Indians and pioneers, but the main one was in Washtenaw county (T. 4 S., R. 5 E., Sec. 12). In 1823 this spring was described as being 16 feet deep, set about with a picket of logs from which the surface water was excluded by means of an embankment. Salt was manufactured here on a small scale, an analysis showing 113.8 grains of salt in 100 cubic inches of the water.* Dr. A. Winchell, in his report of 1860 (p. 59) refers to a salt spring in Ida township, 4½ miles south of the Raisinville quarries. No such surface springs could be located by the present survey, probably owing to the diminished flow from wells and springs. In Berlin township, S. E. ¼, N. W. ¼, Sec. 15, at the place of A. Bondie, the well water is reported as being occasionally salty to the taste. In Lenawee county, north of Deerfield, this phenomenon is more common. Such indications are of interest now only as they suggest the presence of more extensive saline deposits beneath the surface. Undoubtedly the waters obtained from the deep wells of the county are highly charged with salt but no study has been made of them. In but one of these deep wells was there recognized a stratum of solid rock salt (halite) and in this case the report lacks verification. According to a newspaper item, at a depth of about 1,200 feet, a 12 foot stratum of salt was penetrated in the Frey well, near South Rockwood (N. E. ¼, N. E. ¼, Sec. 33, T. 5 S., R. 10 E). This occurrence was not to be expected since the records of the six wells at the Church and Company's plant north of Trenton seem to indicate that the St. Clair and Detroit River beds of salt give out between the most northern and most southerly located wells of their group. Well No. 6 gives a stratum of 33 feet while Nos. 4 and 1 and 3 lying in this order to the east give 30 feet, 26 feet and 25 feet respectively. Well No. 2 lies about 300 feet south of the above and shows but 2 feet of salt while in No. 5, some 800 feet south of the northern row, only a brine was secured with no solid salt. If the rumor in regard to the Rockwood well be founded in fact it will be necessary to assume that minor salt beds were deposited south of the main series after the inland sea had begun to break up into separate bodies of water (Chapter III, § 5).

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*First Annual Report of the State Geologist, 1838, H. R. No. 24, p. 28.

CHAPTER IX.

MINERALS OF MONROE COUNTY.

§ 1. Introduction.

In this chapter it is desired to describe in simple language the native minerals so that they may be readily identified by those interested, even if they possess no previous scientific knowledge or training. After a mineral has been recognized the question of its formation and source becomes of more or less interest and importance, so that the history of the various mineral deposits will be briefly presented. There are excluded from the list all those minerals which were formed to the north and east and which were transported to the region under study by ice or other agency. This chapter will then be of little service in identifying the constituents of the drift boulders strewn over the surface or embedded in the soil. Almost any mineral known may occur in them. It will treat only of those mineral substances which were formed within the limits of the county, some of which are at the surface but most of which are contained in the rock strata and are now met with in the quarries and well drillings. A mineral has been defined as a natural, homogeneous, inorganic substance; but this definition, simple as it is, requires some explanation. It must have been formed entirely through the operation of natural agencies without the intervention of man. The substance itself must have practically the same chemical composition throughout, although it may have mixed with it more or less impurity. It must be of inorganic origin entirely, or if derived from plant or animal originally, its organic structure must have been practically destroyed.

A. Carbonates.

§ 2. Calcite.

This is the most common and widely distributed mineral of the quarries. It is found filling seams and crevices in the limestones and dolomites and forming beautiful sparry lining to fissures and cavities. The calcite may occur as a compact granular mass or in separate, well formed crystals. The crystals are commonly sharply pointed, each point being formed by three pairs of triangular faces, making what is known technically as a scalenohedron.* Such crystallization is known popularly as "dog-tooth spar," because of the resemblance of the crystals to canine teeth. Hubbard, in his early report, refers twice to the "hog-tooth spar" and it is not now certain whether this is simply a misprint or whether he intended to characterize a coarser variety of crystal. Another common form of crystal is the rhombohedron, looking like an oblique prism. Whatever the original crystal, upon being broken the calcite breaks with remarkably perfect cleavage planes parallel to the faces of the rhombohedron. The luster is more or less glassy and the color is various from impurities. The usual color is snow-white to a cream-yellow, but it is sometimes tinged with a variety of color. Clear transparent varieties are known as "Iceland spar," but in general, the mineral is simply translucent. It cannot be scratched with the finger-nail, but is readily scratched with a pin or knife, giving a white powder, the "streak." Its specific gravity is the average for rocks, 2.7. Its composition is calcium carbonate ($Ca\ CO_3$), and it contains by weight, 44% of carbon dioxide (CO_2), and 56% of lime (CaO). This gas may be readily driven off by the application of cold dilute hydrochloric acid to the solid crystal, causing brisk effervescence, so called. The acid of standard strength is prepared by taking four parts of pure water to one part of the acid, giving a 20% mixture. The Monroe calcite crystals have been deposited from percolating water holding calcium bicarbonate $CaH_2(CO_3)_2$ in solution. This form of the carbonate is easily converted into the common variety ($CaCO_3$) which crystallizes where conditions are favorable. Such conditions are commonly found in rock fissures and cavities where there is little agitation of the water which is charged with the carbonate. The finest crystals of calcite in the county are found at the Woolmith quarry, although some good specimens can be procured in the dolomites about Monroe.

§ 3. Aragonite.

This mineral was not identified by the writer amongst his collections but is said to have been found about Monroe.† It has the same composition as calcite, but has less perfect cleavage and is per-

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*See Vol. VI, Part I, appendix, for report on crystallization of calcite.
†Dana's system of Mineralogy, 1892, p. 1086.

ceptibly heavier and harder. It does not show the familiar forms of the calcite crystals, the scalenohedron and rhombohedron. Its crystals may be either simple or compound, or may occur in radiating groups of acicular crystals. The latter is the common crystallization of strontianite (§ 6 of this chapter), and it is quite possible that this mineral may have been taken for aragonite. With the dilute acid calcite and aragonite behave similarly, so that they are liable to be confused with one another, unless crystallization and cleavage can be well made out. Upon being heated as with the blowpipe, they each whiten and glow, but the aragonite crumbles to powder while the calcite does not. The aragonite is liable to contain some strontia, which imparts an intense red color to the flame, making its separation from strontianite more difficult. The lime carbonate of many shells is in the form of aragonite as those of mussels and snails. Some corals and polyzoa form this same substance for their hard structures.

§ 4. Tufa.

This is a cryptocrystalline form of lime carbonate deposited over moss, twigs, leaves, etc., by spring water. The underground water carries the calcium bicarbonate in solution as explained in § 2. Upon having its pressure relieved and being exposed to the air some of the carbon dioxide escapes from the unstable bicarbonate, the monocarbonate results and this is so slightly soluble that it must be precipitated. Deposited thus quite rapidly over the surface of meadows there results an imperfectly crystalline, lumpy mass, more or less porous and open, showing the imprints and moulds of the organisms covered by the water. This is known as calcareous tufa, but where the structure is compact, one layer superimposed directly upon another, it is termed travertine. Iron is generally present in the water, the oxidation of which gives the tufa a yellow to brown stain. The structure of this material, its lightness and occurrence about existing or former springs are sufficient for its identification. A drop of cold dilute acid causes at once a vigorous effervescence, as in the case of calcite. The most extensive deposits of this substance are found to the south of Monroe, near the lake shore (Chapter VIII, §10). Where abundant it is sometimes burned into lime and occasionally used for building purposes. The writer has seen a very pretty country church near Rochester, N. Y., constructed of this tufa.

§ 5. Dolomite.

Just as calcite results from the solution and crystallization of pure limestone, so the mineral dolomite represents the re-crystallized magnesian limestone. Through the agency of percolating water, charged with carbon dioxide gas, this limestone is taken into solution. Little is known definitely in regard to just how it is held, but is probable that the calcium and magnesium carbonates, of which the dolomite is composed, are separate and each in the form of the bicarbonate, $CaH_2 (CO_3)_2$ and $MgH_2 (CO_3)_2$. Under certain conditions these bicarbonates are converted into the monocarbonates, the normal forms, and crystallize together so as to form crystalline dolomite in seams, fissures and cavities. Such occurrences of this mineral, however, are rare although microscopic rhombohedrons make up the granules of oölite and cover the grains of the Sylvania sandstone. The spring waters from beds of dolomite deposit calcium carbonate in the form of tufa but no corresponding deposits of magnesium carbonate (magnesite) were observed. The crystals of dolomite very commonly show curved faces, instead of planes, have a pearly luster and give perfect cleavage. The color is white or pink generally, but may vary from the presence of impurities. The mineral is brittle and has a white streak. It is slightly harder and slightly heavier than calcite, but is distinguished from it most certainly by use of the dilute acid. When a drop of such cold acid is applied to the solid crystal there is almost no action, but if the acid is heated or the dolomite is powdered the effervescence is brisk. This mineral is a double carbonate of calcium and magnesium, having the chemical formula $(Ca\ Mg)\ CO_3$. It contains carbon dioxide (CO_2) 47.8%, of lime (CaO) 30.4% and of magnesia (MgO) 21.7%. Expressed differently it has of calcium carbonate 54.35% and of magnesium carbonate 45.65%.

§ 6. Strontianite.

This is the last of the four minerals from which effervescence may be obtained by the use of dilute acid. A drop of cold acid upon the solid substance causes vigorous effervescence as in the case of calcite and tufa. As found in this county it is of a snow white color forming irregular masses in the cavities and fissures of the dolomitic limestone. Usually it has a loose open structure, composed of globular masses, which show a radially fibrous structure upon being broken. Over their surface and dipping down into the cavities is a layer of fine pyramidal points, producing a fuzzy, frosted appearance.

When the crystals are broken they show both perfect cleavage and uneven fracture faces. The mineral is brittle, gives a white streak, has a glassy to resinous luster and is sub-translucent. The color although usually a pure white may be altered by impurities. The hardness is about that of dolomite (3.5 to 4), so that it may be easily scratched with a knife. Aside from the structure above described, which is quite characteristic, strontianite is easily distinguished from the preceding carbonates by its relatively high specific gravity (3.7), surprising one at once with its weight. If a fragment is moistened with hydrochloric acid and held in the flame of a lamp, candle or gas, or even a burning match, an intense red color is imparted to the flame. This is the familiar "red fire" of the Fourth of July, or campaign celebration and is due to the element strontium, from which the mineral derives its name. The mineral occurs at Stony Point, Point Aux Peaux and Brest, and in the Plum Creek quarries near Monroe, also in the Ida and Little Sink quarries. At the last locality the finest specimens may be obtained in lumps of snowy whiteness the size of the fist and upwards, having been formed in the cavities of the dolomite. At the Ida quarry small masses occur in cavities but some of the upper dolomitic layers are partially converted into strontianite, over the surface of which is spread a layer of slender orthorhombic crystals. This occurrence gives a clue to the origin of the mineral, suggesting that it has resulted from the action of strontium salts in solution acting upon the carbonates of calcium and magnesium. The composition is represented by the formula $SrCO_3$, of which 29.9% by weight is carbon dioxide (CO_2) and 70.1% strontia (SrO). The "tremolite" reported by Houghton in his first report as occuring at Brest was probably this strontianite. Larger quantities than are now in sight would give this mineral a high commercial value since it may be used in recovering beet-sugar from the waste "molasses" (Chapter VIII, § 4). After the process is once started the strontium is recovered and the only loss is that occasioned by the actual sugar loss. According to Prof. Wiley this loss of the mineral strontianite would amount to about 6¼% of the weight of the molasses treated. In the market this strontian carbonate is worth five to six cents a pound.

B. Sulphates.

§ 7. Celestite.

This is another compound of strontium, of much interest and beauty which is more abundant than the above. It is found in the fissures and cavities of the dolomites at Point aux Peaux and Stony Point, about Monroe and in the Raisinville and Woolmith quarries. The finest crystallizations are found at the last mentioned locality, where the mineral is intimately associated with calcite and native sulphur. These crystals are of the flat, tabular variety, with beveled ends and edges and attain a size of 5 to 6 inches in length, by 3 to 4 in breadth and have a thickness of one inch. Typically the color is a beautiful celestial blue from which the mineral derives its name. Some of the masses, however, are perfectly transparent and free from color while others are a pure white, or a deep chocolate brown. The crystals are brittle and break with distinct to perfect cleavage faces, the luster is glassy and the streak is white. The mineral is easily scratched with a knife-point (Hardness = 3 to 3.5), being, generally, a little harder than calcite. A very characteristic property is the high specific gravity (4), it being even heavier than strontianite. From the preceding five carbonates described celestite may be readily distinguished by the action of hydrochloric acid, with which it cannot be made to give an effervescence. Chemically the mineral is strontium sulphate with the formula $SrSO_4$, containing of strontia 56.4% (SrO) and of sulphur trioxide (SO_3) 43.6%. Under the blow-pipe is readily fuses giving the intense red color to the flame. The occurrence of celestite in closed cavities in the dolomite, and its practical insolubility in water and acids, shows that its ingredients must have been introduced through the agency of percolating water and the mineral formed in place. A saturated solution of calcium sulphate (gypsum) would react upon the soluble salts of strontium so as to produce the celestite. The carbonate of strontium was not observed at the Woolmith quarry in association with the sulphate, there appearing to have been sufficient gypsum present to convert all of the original strontium salt into the more stable sulphate. At the Ida and Little Sink quarries only the carbonate was formed, while on the Lake Erie shore both the carbonate and sulphate are associated, indicating that the supply of dissolved gypsum was insufficient.

In the Plum Creek quarries, near Monroe, celestite may be observed undergoing alteration into strontianite, a rather unexpected change, the sulphate being regarded usually as the more stable form. However, a similar change may be produced in the laboratory by boiling the powdered sulphate with solutions of the alkaline carbonates; sodium, potassium or ammonium. It seems very probable that cold water, charged with one or more of the alkaline carbonates might, in the course of time, convert the outer portions of the crystallized sulphate into the carbonate.

§ 8. Gypsum.

Just referred to as probably having been active in the production of celestite is this calcium sulphate, which, although related to it in composition, is still readily distinguished from it by simple physical properties. Either in the form of gypsum ($CaSO_4+2H_2O$), or as the anhydrous variety (anhydrite, $CaSO_4$) this calcium sulphate is widely distributed through the Monroe beds of the county. As given in Chapter III, § 5, this sulphate was deposited directly from the waters of an inland sea, along with the calcium and magnesium carbonates which constitute the beds of dolomite. It would be formed anew wherever free sulphuric acid, derived from the decomposition of pyrite or marcasite, came into contact with calcium carbonate in solution. Calcium sulphate dissolves in 400 parts of water so that surface water, percolating through the dolomites containing gypsum or anhydrite, would take more or less of it into solution. Upon standing quietly in rock cavities and fissures, crystals of gypsum known as selenite, might form. Such crystals occur sparingly at the Woolmith quarry, but were not observed elsewhere. These are perfectly transparent flat crystals, without color and having a glassy to pearly luster. They split readily into thin plates, which may be easily bent without completely separating, but the thin plates are not elastic, as in the case of mica.

The cleavage in this one direction is very perfect. The streak is white and the specific gravity below the average, being 2.3. It is distinguished from all the minerals thus far described by its inferior hardness, since it is readily scratched with the finger-nail. No effervescence can be secured from it by the use of acid. Fine granular to compact masses of gypsum, variously colored from impurities, are known as "plaster" and are valuable for fertilizing purposes. When heated to a temperature of about 392°F. the water in chemical combination is driven off, the mineral crumbles to a white powder and is known as "plaster of Paris." By weight this water (H_2O) comprises 20.9% of the mineral, combined with 32.5% of lime (CaO) and 46.6% of sulphur trioxide (SO_3).

§ 9. Anhydrite.

In the preparation of the plaster of Paris if the gypsum is brought to a temperature of 400° to 650°F. not only is the water of crystallization driven off, but the calcium sulphate practically loses its power to again unite with it and "set." It has closely approached the condition of the anhydrous variety ($CaSO_4$), which is of common occurrence in nature and is known as anhydrite. As generally seen this is a compact or very fine granular translucent mass, of a pure white color and breaking with an uneven fracture. It is brittle and heavier and harder than gypsum. It cannot be scratched with the finger-nail, but is readily scratched with a knife point, giving a white powder. In well drillings it is frequently called "marble," but is easily distinguished from it by the action of the dilute acid. Anhydrite will slowly dissolve in hydrochloric acid, but gives no effervescence, while a small fragment of marble effervesces vigorously as it dissolves. This form of calcium sulphate contains 41.2% of lime and 58.8% of sulphur trioxide. It is less soluble in water than is the gypsum. The presence of anhydrite, or gypsum, in drillings, or dolomites, may be detected by boiling the powder for a short time in hydrochloric acid contained in a test-tube and then allowing the acid to cool. If calcium sulphate was present a mass of very slender needle like crystals will make their appearance. It is not definitely known why the sulphate should have been deposited from the evaporating inland sea in the anhyrous form. Ochsenius has explained it as due to the fact that when the hydrous sulphate (gypsum) is in solution in concentrated sea water with certain salts of potassium it exchanges part of its water for sulphate of potassium, forming polyhalite (KCl) and other salts which remain in solution in the bittern while anhydrite is deposited.*

§ 10. Epsomite.

When the free sulphuric acid of waters percolating through a bed of dolomite acts upon the dissolved calcium carbonate there is formed calcium sulphate as described in § 8 of this chapter. As might be expected this same acid would react similarly upon the magnesium carbonate of the dolomite and give rise to magnesium sulphate ($MgSo_4 + 7 H_2O$), or epsomite. This is so very soluble that ordinarily we should not expect it to be deposited, but it is a common ingredient of mineral waters. Sometimes it occurs as a delicate efflorescence over the surface of rocks in dry fissures, the galleries of mines and caves. In the Ida well (see Chapter III, § 8) a 100 foot layer of this substance was reported and a sample saved. The sample proved to be epsomite, but it is believed to have come from a cavity or fissure and not to represent the entire bed which was probably a dolomite rich in anhydrite. Epsomite is now on the market at 2½ cts. per pound by the barrel. It contains by weight 16.3% of magnesia (MgO), 32.5% of sulphur trioxide (SO_3) and 51.2% of water (H_2O). It occurs usually in elongated slender orthorhombic crystals, white in color, with a glassy to earthy luster, breaking with perfect to imperfect cleavage. It can be scratched with the finger-nail. (Hardness = 2½), giving a white powder. Its specific gravity is but 1.75 so that it appears very light. On account of its easy solubility it has a pronounced taste, which is salty to bitter. Upon being heated it gives off much acid water in which it liquefies.

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*Quoted from Mich. Geol. Sur., Vol. V, Pt. II, p. xvii.

C. Chlorides.

§ 11. Halite.

Owing to the possibility of the occurrence of rock salt ($NaCl$) in the northeastern part of the county (see Ch. VIII, § 12), a description of this mineral is here inserted. The common form of crystal is the cube, parallel to the faces of which it breaks readily with very perfect cleavage. When pure it is colorless and transparent but it is frequently rendered translucent and of a variety of colors from impurities. It can be scratched with the finger-nail, with some difficulty, giving a white powder. When pure its specific gravity is 2.1, so that it appears light. The most characteristic property is its familiar saline taste, being readily dissolved in water. It gives no effervescence with the acid. In the blow-pipe flame it fuses and imparts an intense yellow color, owing to its sodium, which makes up 60.6% of the mineral, while the remaining 39.4% is chlorine. It occurs in solid beds in the earth only where the subterranean waters have not had free access to it. It is believed to have been formed through the concentration of the waters of an inland sea.*

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*See Chapter III, 5; also Geol. Sur. of Mich., Vol. V, Part II, pp. ix to xix.

D. Sulphur and Sulphides.

§ 12. Sulphur.

Closely associated with the celestite and calcite crystals at the Woolmith quarry are beautiful crystalline masses of brilliant yellow sulphur, contrasting gorgeously with the blue of the celestite and the creamy white calcite. Attention was first called to this occurence of native sulphur by the writer in 1895.*

The sulphur is confined mainly to the ellipsoidal cavities in a soft, open bed of dark brown dolomite from one to three feet thick. These cavities vary in size from a fraction of an inch to three feet in their greatest horizontal diameter. Some of these cavities are completely filled with the sulphur, which at times shows crystal faces, but generally the sulphur shows only the rough conchoidal fracture characteristic of such crystalline masses. More frequently the cavity has a lining of celestite and calcite and only the central portion contains the sulphur, showing that its deposition began later than that of these two minerals. It was estimated by the foreman at the time of the survey, four years ago, that between 400 and 500 barrels had been removed, most of which was carried away by visitors. The present market value of such sulphur is 2½ cents per pound. This mineral is very easily distinguished from all others by its brilliant yellow, its resinous luster and conchoidal fracture. It is quite brittle, can be scratched with the finger-nail, has a specific gravity of but 2 and is translucent. It melts readily and burns with a blue flame emitting irritating odors of sulphuric dioxide (SO_2). It is insoluble in water and is not affected by acids. When the deposits were first examined by the writer in 1895 there entered the quarry from the "sulphur bed" a stream of water charged with hydrogen sulphide gas (H_2S). As the water trickled down the face of the quarry wall and flowed over the bottom there was deposited a mealy white precipitate of sulphur, resulting from the decomposition of this gas. Where this deposit was longest exposed it showed a slight yellow color. From the cavities of the dolomite specimens of whitish yellow sulphur were collected, having the same mealy appearance, but containing throughout small irregular masses in the crystalline condition. There is no room for doubt then that the sulphur has resulted from the decomposition of hydrogen sulphide gas, introduced through the agency of percolating water, and that it has gradually passed from the mealy to the crystalline condition. The gas has been formed in the rocks through the decomposition of the next two minerals to be described.

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*American Journal of Science, Vol. L, Third Series, pp. 246-248; also in a paper presented to the Michigan Academy of Science, Lansing, December, 1895.

§ 13. Pyrite and marcasite.

These are two minerals which have the same chemical composition (FeS_2), being compounds of iron and sulphur. They contain by weight 53.4% of sulphur and 46.6% of iron. They are not often seen at the surface, but are abundant enough in the rock strata to give character to the spring and well water and to be indirectly responsible for the formation of a number of the minerals described in this chapter. They each have a brassy luster and color, a specific gravity approaching 5 and are hard enough to make a scratch upon glass. They are brittle, break with an uneven fracture, are opaque and have a black streak. When heated sufficiently they are decomposed, the sulphur burns with its characteristic blue flame and leaves behind a dark mass which is now magnetic, owing to the free iron. The pyrite is generally found in beautifully perfect cubes of various sizes, having a golden color and luster, which causes it frequently to be mistaken for gold. In the dolomite of the Plum Creek quarries seams and incrustations of crystallized pyrite occur, in tarnished condition. The crystals are very small, giving the mineral a fine granular appearance, and are mainly octahedrons. This is the only locality at which pyrite was found. The marcasite is of a whiter yellow, does not occur in cubes, but usually in flattened concretions showing radially fibrous structure, and is more subject to decomposition than the pyrite. The formation of these two minerals through the agency of organic matter and oxide of iron was explained in Chapter II, § 11. When either of these minerals is in contact with water for a sufficient length of time, double decomposition takes place. The sulphur unites with hydrogen of the water to form hydrogen sulphide gas (H_2S), which is readily held in solution by the underground water and gives rise to "sulphur" springs and wells. The iron of the pyrite, or marcasite, is readily oxidized and if carbon dioxide be present will be converted into iron carbonate ($FeCO_3$), taken into solution and will impregnate the water with iron, forming "chalybeate springs or wells" (chapter VIII, § 10). The hydrogen sulphide itself may unite with oxygen to form sulphuric acid (H_2SO_4), which may unite with iron, calcium or magnesium to form the series of sulphates found in the natural waters. Pyrite and marcasite are very undesirable ingredients of building stone because of their tendency to decompose, whereby the stone itself is disintegrated and discolored through the oxidation of the iron left behind.

E. Oxides.

§ 14. Bog iron ore (limonite).

Before the rich deposits of iron ore were located in the Lake Superior region and Missouri this impure form of iron oxide was eagerly sought. Hubbard in his original survey of the county located deposits in Secs. 19 and 25, of Summerfield township and called attention to indications in Sec. 3 (T. 9 S., R. 7 E.) of Bedford, and also in London.*

During the present survey other records were obtained of similar deposits. In section 23 of Milan (N. W. ¼, S. E. ¼) N. D. Baird struck bog ore at a depth of five feet while ditching. It is said to occur also one mile south of Petersburg upon the place of Enos Plomodore (S. W. ¼, N. W. ¼, Sec. 10). In the N. W. ¼, N. W. ¼, Sec. 26 of Bedford, bog ore occurs along a ditch for a distance of ten rods. This mineral occurs in marshes, where it is now forming, and in the beds of former swamps now drained and under cultivation, in beds of varying thickness. Irregular rusty lumps are found in the soil, having a dull earthy luster and without crystalline structure. Their high specific gravity (3.6 to 4) at once distinguishes them from irregular lumps of tufa or clay. The mineral breaks with an irregular fracture, is opaque, can be scratched with difficulty with a knife-point and gives a yellowish brown powder. It is an oxide of iron in combination with water, its formula being $2Fe_2O_3+3H_2O$. When pure it contains 59.8% of iron, 25.7% of oxygen, and 14.5% of water. When mixed with considerable clay it is known as "yellow ochre" and has been used as a paint. Upon the application of sufficient heat the water of crystallization is driven off and the oxide is converted into the red oxide known as hematite (Fe_2O_3). This also exists in a soft earthy form known as "red ochre," a bed of which three rods square, and one to two feet thick, was located in Sec. 21 of Bedford township, by Hubbard.†

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*Second Annual Report State Geologist, 1839, H. R. No. 23, page 112.

†The first volume of the American Journal of Science in 1819 announced the "Discovery of American Cinnabar and Native Lead." (pp. 433-4.) A portion of a letter from J. L. Comstock, of Hartford, Connecticut, was published by the editor, which contained an extract from a letter written by B. F. Stickney, Indian Agent

When clay of a brown or yellow color from the presence of the hydrous oxide is burned, as in the manufacture of brick and tile, the conversion to the red oxide takes place in the furnace and a total change in color results. The iron for the formation of beds of bog ore is derived from the soil of the area which is drained into the marsh. It is introduced into the soil from the iron bearing minerals which have contributed to its formation, as hornblende, pyroxene, black mica, pyrite, siderite, etc., of the crystalline rocks. Upon the decomposition of these and other minerals iron is liberated which soon unites with the oxygen of the air forming generally the yellow hydrous oxide. In this form it is abundant in the soil and is insoluble, but must be transported before any beds can be formed. This is accomplished through the agency of decaying organic matter in the soil. The carbon of this organic matter has a stronger affinity for oxygen than has the iron, and some of the oxygen is torn from the iron oxide forming ferrous oxide (FeO). The carbon dioxide (CO_2) formed in consequence may unite with the ferrous oxide and form ferrous carbonate ($FeCO_3$). This carbonate is somewhat soluble in water containing carbon dioxide and is leached from the soils and transported by the streams to the swamps. Upon standing the carbon dioxide of the carbonate is exchanged for oxygen of the air with the formation of the oxide and the liberation of the CO_2. The oxide being insoluble must be precipitated and usually goes down as the hydrous form, that is, the bog ore variety. Beds rarely exceed one to two feet in thickness. From this method of formation it is apparent that the ore will be mixed with sand, clay and other impurities. For this reason and the manner of occurrence this ore has no commercial value at present. Shaler has suggested that as top dressing this ore adds binding qualities to limestone used in the construction of stone roads.

§ 15. Crystallized quartz.

The Sylvania sandstone has been described as consisting of countless millions of quartz crystals, each a hexagonal prism terminated

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at Fort Wayne. The latter says, "I have found a black and garnet colored sand, in great abundance on the shore of Lakes Erie and Michigan, this is sulphuret of mercury, and yields about sixty per cent. It is so easy to be obtained, and is so convenient a form for distillation, that it must become an important article of commerce." In the second volume of the same journal (p. 170) the editor publishes a letter direct from Mr. Stickney, dated "Port Lawrence, Michigan Territory, Mouth of the Miami of the Lakes, June 17th, 1819," in which he says, "From the mouth of the Vermillion, round the whole shore of the western end of Lake Erie, on the shores of the Detroit river, Lakes St. Clair, Huron, and Michigan, the banks are streaked with small reefs of this black and red sand of cinnabar. The whole body of the soil is interspersed with this sand through the whole of this extensive district of country." The editor announced that a sample of the sand, enclosed in a letter had been lost. In his Catalogue of American Minerals, published in Boston, 1825, by Dr. Samuel Robinson this occurrence of cinnabar is noted (page 239). The red and black sand referred to must have consisted of oxides of iron.

by one or two hexagonal pyramids. The formation of these crystals through the secondary enlargement of rounded sand grains has been presented in Chapter III, § 6.

Water saturated with silica (SiO_2) and standing quietly in fissures and cavities sometimes forms an incrustation of quartz crystals. If no impurities are present the crystals are transparent and without color being known as "rock crystal." Limited quantities of this occur at the Navarre quarries on Plum Creek. When colored purple the quartz is called "amethyst" and this variety was observed at Brest by Dr. Winchell and is reported by Dana as occurring here and at Point aux Peaux and Stony Point. Quartz is readily distinguished from all the other minerals described by its simple physical properties. The form of the crystal is entirely characteristic when this can be made out, the hexagonal prism terminated with the hexagonal pyramid. It has a glassy luster and has no plane cleavage faces, but a conchoidal fracture. Its specific gravity is 2 2-3. It cannot be scratched with a knife or file and scratches glass very easily. It is insoluble in pure water, is unaffected by the ordinary acids and is infusible before the blowpipe. Heated with soda, however, it readily melts and forms glass. It consists, when pure, of 46.7% of silicon and 53.3% of oxygen.

§ 16. Chert.

This is a variety of uncrystallized or rather cryptocrystalline quartz (SiO_2) commonly known as "flint." It is, however, too impure for flint, since it contains a considerable percentage of calcium carbonate. From its resemblance to horn it has been called "hornstone," and owing to its abundance in our Dundee formation gave to it the name of Corniferous (*cornu*, a horn). As found in Monroe county its color is drab to brown, with a dull to subresinous luster. It is opaque to sub-translucent and is very brittle, breaking with a coarse conchoidal fracture and giving sharp edges. It readily strikes fire with steel and scratches glass with about the same ease as crystallized quartz. Its specific gravity is not perceptibly different. It occurs in the Monroe beds and the Dundee formation in seams and crevices, in irregular nodules, and as thin beds between the strata of the dolomite and limestone as previously described. In the quarries most of it is seen on the Macon and at Dundee, where it forms thin beds. It frequently encloses fossils in silicified condition, in the cavities of which the silica has sometimes crystallized, giving a thin layer of minute crystals suggestive of frost and known as "drusy quartz." The formation of this chert and the origin of its silica have been discussed in Chapter II, § 22. It is too impure for the manufacture of glass, for which flint is used, and its brittleness and lack of binding qualities unfit it for macadamizing purposes. Its hardness, manner of breaking and inertness to the weather made of it a most useful mineral for primitive man. From it he made his spear and arrow-points with which to capture game, the implement with which to prepare, and the spark of fire with which to cook such game. Quarries of a good grade of chert were of more value to him than the richest gold mines of the Klondike or the diamond fields of Kimberly.

F. Phosphates.

§ 17. Apatite.

This is a mineral reported by Winchell and Dana as occurring at Brest, Point aux Peaux and Stony Point, but a careful search failed to reveal any of it at the present time. It is a phosphate of calcium, with the formula $(CaF) Ca_4 P_3 O_{12}$, occurring sometimes in limestones, but more commonly in the crystalline rocks. It contains of P_2O_5 42.3%, of lime (CaO) 55.5%, and of fluorine 3.8 %. When properly prepared it is valuable for fertilizing purposes since it supplies the soil with both lime and phosphorus. Its common mode of occurrence is in the form of elongated hexagonal prisms, of a brown or green color. Its luster varies from glassy to resinous, the mineral looking as though it were slightly oily. It is subtranslucent to opaque, is quite brittle and shows only imperfect cleavage across the prisms. Its specific gravity is a little above the average of rocks (3.2), while its hardness permits of its being scratched, with some difficulty, with a knife-point. It gives no effervescence with the acids. This assemblage of characters readily distinguishes apatite from any other mineral encountered in the county.

G. Hydrocarbons.

§ 18. Asphaltum.

Black, amorphous carbonaceous matter has been mentioned as occurring at various quarries, filling seams and crevices in the dolomites and limestones. Thin layers, more or less continuous, frequently occur between the beds, rarely attaining a thickness of one-quarter inch. Certain beds at the Woolmith quarry are impregnated with this substance to such an extent that the stone is considerably darkened by it and Mr. G. F. Smith has suggested its use for asphalt pavements, believing that by grinding and heating there would be found sufficient asphaltum to bind together the fragments. As seen in the county, both at the quarries and in the well drillings, the substance is always very impure. If held in a flame it burns for a short time, giving a bright yellow flame and oily odor, but does not perceptibly diminish in bulk. There is usually not sufficient carbonaceous matter present to continue the combustion after the fragment is withdrawn from the flame. When pure, asphaltum is very brittle, of a jet black color and pitchy luster, breaking with a coarse conchoidal fracture. It is soft and very light, its specific gravity ranging from 1 to 1.8. It readily melts and burns with a bright yellow, smoky flame. It is more or less soluble in turpentine, ether and alcohol, but not in water. It has formed where now found by the accumulation of rock oil, which has gradually lost its more fluid constituents and hardened. It is thus of organic origin, has no definite composition, consisting mainly of carbon, hydrogen and oxygen, and cannot be regarded as a true mineral.

H. Key to Minerals.

§ 19.

The following simple key will enable those interested to readily determine the minerals of the county which are encountered in the quarries and well drillings. It will be of no service in identifying the ingredients of the common field boulders. The acid referred to is hydrochloric acid and is prepared by taking a small quantity of commercial strength and adding four times its volume of pure water. In using this a drop of the cold acid is first applied to the solid mineral. If the action is not vigorous the mineral may be reduced to powder at one place and the acid applied, or a fragment may be placed in acid in a test-tube and then heated. After the mineral has been traced, its description, as given in this chapter, should be carefully reviewed for the purpose of verification.

TABLE XIV.—KEY TO THE MINERALS OF MONROE COUNTY.

Effervesces with dilute acid.	Incoherent.				White and mealy looking, associated with muck. Action with acid vigorous.	Marl.
	Coherent. in lumps or crystals.	Heavy.			Occurs in irregular lumps, covered with fine crystal points. Action with acid is vigorous; colors flame an intense red.	Strontianite.
		Medium.	Acid action on solid mineral is	Vigorous.	Occurs in sharp pointed crystals, or breaks into rhombohedrons. Does not crumble on being intensely heated.	Calcite.
					Occurs in six-sided prisms, or radiating groups of needle-like crystals. Crumbles on being heated.	Aragonite.
				Slight.	Action is increased by powdering the mineral.	Dolomite.
		Light.			Irregular brownish lumps of a loose, open structure. Action with acid vigorous.	Tufa.
Does not effervesce with dilute acid.	Scratched with finger-nail.	Easily.	Not crystalline. Occurs in irregular, earthy masses.		Rusty yellow to brown.	Yellow ochre.
					Cherry red.	Red ochre.
			Crystalline.		Flat transparent crystals, separable into thin, flexible plates.	Selenite.
		With some difficulty.	Soluble in water, will not burn.		Small white needle crystals, bitter taste.	Epsomite.
					Breaks into cubes, salty taste.	Halite.
			Insoluble in water, will burn.		Color yellow, burns with blue flame.	Sulphur.
					Color black, burns with yellow flame.	Asphaltum.
	Not scratched with finger-nail.	Luster glassy.	Will not scratch glass.		Very heavy, perfect cleavage, flat tabular crystals.	Celestite.
					Moderately heavy, imperfect cleavage, six-sided prisms.	Apatite.
			Will scratch glass easily.		Average specific gravity, no cleavage, conchoidal fracture. Occurs in six-sided prisms with pyramids.	Quartz.
		Luster metallic.			Granular or in isolated cubes or octahedra, golden yellow color, slightly tarnished.	Pyrite.
					Flattened concretions, radially fibrous structure, silvery yellow, tarnished.	Marcasite.
		Luster dull.	Very heavy.		Rusty irregular lumps, generally loose in the soil.	Bog iron ore.
			Medium weight.		Drab or brown, conchoidal fracture, scratches glass easily.	Chert.
					Pure white, uneven fracture, will not scratch glass.	Anhydrite.

CHAPTER X.

FOSSILS OF MONROE COUNTY.

§ 1. General nature of fossils.

Embedded in the rocks which have been described, and imprinted upon the surfaces of the strata are the remains of former plant and animal life. From their resemblance to forms still in existence we know that they lived in the waters of an ocean charged with salt. From a study of the deposits which have been superposed, here and elsewhere, upon these strata we are forced to the conclusion that this ocean existed in Michigan so long ago that the time can be estimated only in millions of years. Nowhere in the county, or adjoining regions, have there been found embedded in the rocks any trace of forms higher than the lowest order of fishes. When we consider the advance which has been made biologically since that time we are still better able to grant to these fossils the respect which is accorded great age. When such objects first began to attract attention during the 15th and 16th centuries they were regarded as "sports of nature," as though produced through Nature's effort at self amusement. By some writers they were thought to be due to the "influence of the stars," and by others to have resulted from the fermentation of certain fatty matter in the earth through the agency of heat. Early in the 16th century Fracastoro and Leonardo da Vinci declared that they represented the remains of organisms which had once lived where they are now found, a view that was savagely combatted for 200 years. As this simple truth finally prevailed over prejudice and superstition the question arose as to the time of their destruction, it being assumed that their death was simultaneous and produced by some widespread natural catastrophe. For a long time and by many the Noachian deluge was regarded as the cause of this universal destruction of life, of marine forms as well as those which lived upon the land. During the 18th century the discussions covered the method of extinction and entombment, the formation and displacement of the rocks containing them, the succession of forms and their relation to living species. By the middle of the century it had been shown by Marsilli, Spada and Schiavo that fossils are not scattered at random through the rocks, but that there is an orderly succession. By the close of the century this truth had borne fruit. William Smith, an English engineer, suggested their use in recognizing and correlating strata, since beds of the same age should contain the same assemblage of fossils. During the century just closing thousands of forms have been described and figured, their groupings in the strata investigated, and the solution of the problems of development undertaken. From such study beds of economic importance may be located in the geological series and the physical and biological history of the earth deciphered.

By Lyell a fossil was defined as any body, or the traces of the existence of any body, whether animal or vegetable, which has been buried in the earth by natural causes. The cast or mould of any organism whatever, the imprint of a leaf or the foot print of an animal would thus come within the definition. So also would the body of a sheep buried by yesterday's land slide, but probably would not have been regarded as a fossil by Lyell himself. It is now generally understood that the form, in order to be considered a true fossil, must have lived during a previous geological epoch.

§ 2. Conditions of preservation.

With reference to their manner of preservation fossils may be separated into four classes. First, those in which the organic matter itself has been preserved as in the case of some of the plant remains to be described. Here the carbonaceous matter of the tissue is still in existence and makes up the fossil, although it has been mineralized. Rock oil represents such preserved organic matter which has become separated from the organisms of which it at one time constituted a part. In this same class should be placed bones, shells, corals, etc., which still retain the matter of which they were originally formed. In a second class of fossils this original matter has been replaced, particle by particle, by other mineral matter giving rise to a "petrifaction." The replacing mineral is most commonly calcite or silica, but may be pyrite, sulphur, iron oxide, etc. Very frequently, as in the case of silicified wood, the minute details of even the microscopic structure are most perfectly reproduced. In still a third class of fossils the organism itself, or some part of it, has left its impress upon a soft mass capable of retaining the form. After hardening there is thus produced a mould of the original object. Such moulds of shells are quite common in the dolomites and occasionally a coral, or crustacean, is similarly preserved. Imprints of leaves, burrows and channels, footprints, etc., belong to this class. Finally, upon the withdrawal of the organism, or its removal by decay or solution, soft mineral matter may settle into the mould and form a cast. The most common form of cast is that of the entire exterior, but internal casts of shells are also not uncommon in the county. These are produced by the fine sedimentary material working its way into the internal cavity and there hardening. When the shell is dissolved away by percolating water a space is left between the mould and the internal cast. This occasionally becomes filled with sediment, sometimes with crystalline material and a cast of the shell itself is formed, which very much resembles a true petrifaction, but differs from it in not showing any of the real shell structure.

§ 3. Fossils of the Monroe beds.

The beds of dolomite are in general quite poor in fossils, but at certain horizons and in certain localities moulds and casts of brachiopods and gasteropods are abundant, crinoids, corals and bryozoan remains are found occasionally and lamellibranchs rarely. Worms, cephalopods and crustaceans are the only other animal groups that are known to be represented in this series of beds. There is nothing here to indicate that fish had yet come into existence, not a tooth, scale, plate or spine having yet been found. In nearly all cases the shell substance has been dissolved and nothing has been deposited in its place, so that the identifications have to be made upon the moulds, imprints, external and internal casts. A large number of such fragments were collected which are unidentifiable, either because of their state of preservation or because they represent species not yet described. The writer feels reasonably certain of the list below enumerated. A study was made of the fossil contents of the Monroe beds by Rominger and reported upon in 1876.[*] From these same beds in western Ohio, Whitfield identified and described a number of forms in a paper read before the New York Academy of Science in 1890.[†]

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[*] Michigan Geological Survey, Vol. III, Pt. I, pp. 31 to 34.

[†] Description of Fossils from the Palæozoic Rocks of Ohio. Ann. N. Y. Acad. of Science, 1890; pp. 505 to 622. Also Geol. Surv. of Ohio, Vol. VII, pp. 407 to 493. Plate V accompanying this paper is reproduced as plate XVII of this report through the kindness of Prof. Whitfied and the Ohio Survey, although it contains some forms not yet discovered in the county.

SPIRIFER VANUXEMI, Hall. Palæontology of New York, Vol. III, 1859; p. 198, plate VIII, figs. 17 to 23.

Orthis plicata, Vanuxem. Geol. Rep. Third District of New York, 1842; p. 112, fig. 1.

A few specimens of this species were found in the beds about Monroe, but they are not common. Adult forms of the type figured on plate XVII, figures 4 and 5, occur and also immature specimens similar to those drawn and described by Hall.

MERISTELLA LÆVIS, Vanuxem, sp.

Atrypa lævis, Vanuxem. Geol. Rep. Third District of New York, 1842; p. 120, fig. 2.

Merista lævis, Hall. Palæontology of New York, Vol. III, 1859; pp. 247-8, plate XXXIX, figs. 1 to 4.

Meristella lævis, Hall. Thirteenth Ann. Rep. of Regents on the N. Y. State Cabinet, 1860; p. 75.

Cf. *Whitfieldella lævis?*, Grabau. Bull. Geol. Soc., Am. 1900, Vol. XI, p. 369.

This is the most common and most widely distributed fossil in the county, being seen at nearly all the localities where the beds of dolomite are exposed. Its general form is shown in figures 6 and 7 of plate XVII.

MERISTELLA BELLA, Hall. Thirteenth Ann. Rep. of the Regents on the N. Y. State Cabinet, 1860; p. 75.

Merista bella, Hall. Palæontology of New York, Vol. III, 1859; p. 248, plate XL, fig. 1, a-p.

This form, which much resembles the preceding and is found in association with it, is figured on plate XVII, figures 8, 9, and 10. The general outline is seen to differ from *Meristella lævis*, and each valve possesses a sinus the meeting of which give a more emarginate character to the front.

NUCLEOSPIRA ROTUNDATA, Whitfield. Ann. N. Y. Academy of Science, 1882; p. 194.

Se plate XVII, figures 11 to 14. The best preserved specimens of this species were collected from the beds of the Woolmith quarry where they are associated with Meristella.

RETZIA FORMOSA. Hall, sp.

Waldheimia formosa, Hall. Tenth Ann. Rep. of the Regents on the New York State Cabinet, 1857; p. 88.

Trematospira formosa, Hall. Palæontology of New York, Vol. III, 1859; pp. 215-216, plate XXXVI, figs. 2, a-u.

Rhynchospira formosa, Hall. Palæontology of New York, Vol. III, 1859; p. 485, plate XCV A, figs. 7-11.

This beautiful little shell is shown on plate XVII, figures 15 and 16. Quite perfect moulds are sparingly found, apparently more frequently at the Little Sink and Little Lake quarries. These specimens agree with those described from Ohio in being smaller than those from New York, figured by Hall.

PENTAMERUS GALEATUS, Dalman, sp.

Atrypa galeatus, Dalman. Vet. Acad. Handl., 1827; p. 130.

Pentamerus galeatus, Hall. Palæontology of New York, Vol. III, 1859; pp. 257-9, plate XLVI, figs. 1, a-z; plate XLVII, figs. 1, a-m.

Gypidula galeata.

Fragments of this large brachiopod are found about Monroe, one quite complete ventral valve having been secured, from which the identification was made.

PENTAMERUS PES-OVIS, Whitfield. Ann. N. Y. Acad. Science, 1882; p. 195.

This form was named because of the resemblance of its internal casts to sheeps' feet. See plate XVII, figures 18-22. These casts are in the dolomite about Monroe.

GONIOPHORA DUBIA, Hall, sp.

Modiolopsis dubius, Hall. Palæontology of New York, Vol. III, 1859; p. 264, plate XLIX, figs. a-e.

Goniophora dubia, Whitfield. Geol. Sur. of Ohio, Vol. VII, 1893; pp. 415-16, plate I, figs. 24-26.

Specimens of lamellibranchs are very infrequently met with in the Monroe beds. A number of well preserved forms of this species, however, were collected from the Plum Creek quarries. They are shown on plate XVII, figures 24-26.

PTERINEA AVICULOIDEA, Hall, sp.

Megambonia aviculoidea, Hall. Palæontology of New York, Vol. III, 1859; pp. 274-5, plate XLIX, figs. 7 and 8; plate XLIX A, fig. 8.

Pterinea aviculoidea, Whitfield. Geol. Rep. of Wis., Vol. IV; p. 322, plate XXIV, figs. 6 and 7.

The internal cast of the left valve of a large specimen of this, or a closely related species, was found in Daniels' quarry at the head of Ottawa Lake. The species is reported from the county by Rominger and from the Ohio beds by Whitfield. See plate XVII, fig. 23.

LEPERDITIA ALTA, Conrad, sp.

Cytherina alta, Vanuxem. Geol. Report of the Third Dist. N. Y., 1842; p. 112, fig. 6.

Leperditia alta, Jones. Ann. and Mag. of Nat. Hist., Vol. XVII, second series, p. 88.

This peculiar crustacean is shown in side view on plate XVII, figure 27. It is especially characteristic of the Waterlime division of the Lower Helderberg. It is of rare occurrence in the county but was found around Little Lake, in Bedford township. There occurs in the same vicinity a minute Leperditia of the same general form as the above but with a length of only .05 to .06 of an inch. The prominence of the eye tubercles indicates that it is distinct from L. alta and no intermediate forms were observed.

SPIRORBIS LAXUS, Hall. Palæontology of New York, Vol. III, 1859; p. 349, plate LIV, figs. 18, a-e.

The coiled tubes of very small marine worms are abundant about Newport and Monroe and at the Little Sink and Little Lake quarries. They appear to be identical with Hall's forms from the Lower Helderberg of New York. The tubes are circular in cross section, show from 1½ to 3 coils, with a diameter of .02 to .04 of an inch. Usually nothing but the minute cavity remains, but occasionally a cast is found which shows 11 to 12 annular ridges in the last half whorl. Sometimes a considerable part of the last whorl is free from the remainder of the coil and irregularly extended. The Little Sink specimens are coarser than those found about Monroe and may represent another variety. Associated with them are tortuous vertical channels, which represent the burrows or tubes of larger worms, to which the generic name *Scolithus* has been applied.

In addition to the above identifiable species a large number of fragments were collected which cannot be satisfactorily specifically determined. These include Conularia, Tentaculites, Strophodonta, Orthis, Spirifer, Conocardium, Platyceras and numerous other gasteropods, lamellibranchs, trilobites, crinoids, cyathophylloid and favositoid corals.

Several types of plant fossils occur within the limits of the county. From what was said concerning the formation of the oölite granules and the associated structure in Chapter III, § 7, it is evident that these must be regarded as fossils. Under the same head would come the vertical channels found in one of the silicious dolomites at the Woolmith quarry, Chapter IV, § 4. These are supposed to represent the casts of marine plant stems about which the sandy, dolomitic slime settled and partially hardened. Upon the upper surfaces of certain ledges at Newport, Plum Creek and Little Lake quarries carbonized plant remains occur in abundance. The stems of one form are straight, unbranched and flattened and appear to be longitudinally creased by about eight furrows. The diameter of the flattened stems change but little in an inch or two and equal .06 to .07 of an inch. There is evidence of irregular jointing. Associated with this form is a more delicate variety which branches dichotomously and has a breadth of but .01 of an inch. A still coarser and less flattened type of stem is seen about Newport, hava breadth of .10 to .13 of an inch. These all very probably are remains of marine algæ. Of these remains which Rominger found at Newport he says the following:*

> "The vegetable remains are of various kinds. Some are band-like, compressed stems, which sometimes bifurcate, and are of a jointed structure. On certain portions of these stems, annular cicatrices are disposed in remote rows, in shape resembling the pores of the tube of Favosites. Another kind of stem is narrower, more remotely jointed, and each joint is surrounded by a verticil of long, narrow leaves."

§ 4. Fossils of the Dundee formation.

The limestones exposed in the Dundee and Macon quarries are exceedingly rich in fossils. Upon weathered surfaces, under the magnifier, they are seen to consist of one mass of minute fragments in which, here and there, entire forms are embedded. The same species occur here as in the Trenton quarries where the opportunities for collecting are far better. Therefore detailed description of this fauna may be left to the Wayne county report. Upon the other hand all the forms found at Trenton are liable to be encountered in the Monroe county exposures. An extensive collection was made from the Sibley quarry, just north of Trenton, but there has not been time for its study. The following species were collected from this locality by Dr. Rominger:

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*Mich. Geol. Sur., Vol. III, part I, p. 32.

Atrypa reticularis, Linnæus, sp.
Spirifer gregarius, Clapp.
Spirifer acuminatus, Conrad.
Orthis Livia, Billings.
Strophodonta concava, Hall, sp.
Strophodonta perplana, Conrad, sp.
Paracyclas elliptica, Hall.
Conocardium subtrigonale, D'Orbiguy.
Pleuronotus Decewi, Billings, sp.
Phacops bufo, Green, sp.
Proetus crassimarginatus, Hall, sp.
Dalmania selenurus, Eaton, sp.
Stromatopora textilis, Rominger.
Stictopora Gilberti, Meek.
Zaphrentis prolifica, Billings.
Zaphrentis gigantea, Lesneur.
Heliophyllum Halli, Edwards and Haime.
Heliophyllum corniculum, Lesueur, sp.
Favosites turbinatus, Billings.
Favosites hemisphericus, Troosy, sp.

In addition to the above species the following genera were represented by unidentified species. Fenestella, Polypora, Orthoceras, Gomphoceras, Gyroceras and Nautilus. Spines, plates, bones and teeth of sharks are found, most of them belonging to Onychodus sigmoides (Newberry), of the Upper Helderberg of Ohio.

In regard to the correlation of the fauna of the upper and lower Helderberg, Dundee and Monroe beds, reference should be made to Schuchert's paper already cited.[*]

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[*] Bull. Geol. Soc. of Amer. pp. 241 to 332. See also paper by A. W. Grabau in the same volume, pp. 347-376, on the Siluro-Devonian contact in Erie county, New York. It is only fair to Prof. Sherzer to say that the important papers by Clarke and Schuchert, Williams, and Grabau referred to, have appeared during the proof reading, and the foot notes referring to the same and some slight changes in the text have been made largely by myself. While Prof. Sherzer has had a chance to see most of them, they may not be such as his deliberate judgment would approve, and in any case he would doubtless give these papers more worthy and ample treatment did time permit. It will appear clear upon careful reading of them that Clarke and Schuchert have excluded from the (Lower) Helderberg the Tentaculite

It seems clear that the Dundee fauna corresponds to that of the upper Helderberg, the Becraft limestone (Upper Pentamerus) of Darton and Schuchert, and that the bulk of the Monroe beds, especially those below the Sylvania sandstone have a Silurian fauna akin to that of the Manlius limestone or Waterlime. So far as yet appears there is no reason for cutting off any of the Monroe beds faunally from their lithological representatives, and considering them Devonian.

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or Manlius limestone, which was considered originally its lowest member. In the western part of New York, Ohio and Monroe county, Michigan, the beds just above are wanting, and the unconformity which Grabau has pointed out exists. Hence naturally the Manlius limestone fauna has come to be regarded as typical Lower Helderberg in the region of the Great Lakes. This is regarded by all as Silurian. Whether the balance of the Lower Helderberg should be so regarded we have no occasion to decide. It may be noted, however, that if Hunt is right as to the intercalation of Corniferous in the Salina (p. 52), we must either include all the Salina as Devonian, or give up the "Devonian facies" as a criterion.—L.

GENERAL INDEX.

A.

Acicular structure............... 86
Adrian.............32, 38, 133, 134,136
Alcona moraine..............140, 143
Algæ..........................66, 226
Algonkian Indians............... 6
Algonquin Lake.................. 144
Alluvium 12, 110, 111
Alpena, Thickness of Hamilton at. 32
Alumina. See CLAY and ANALYSES also.................. 26
Altitudes 106
  of R. R. stations............ 108
  of beach lines............... 143
  of Sylvania sandstone....... 54
Amethyst....................... 216
Ammonia, source of, in soil........ 166
Analyses, and composition of—
  cement rocks............181, 182
  farm products............... 159
  limestone and dolomite 76, 87, 92, 95, 150, 176, 178
  minerals..............204 to 217
  sandstone.................. 57
  soils........151, 152, 155, 156, 163
  sugar beet limestone........ 179
  water...................... 201
Anhydrite 52, 67, 68, 69, 73, 209, 210, 219
Ann Arbor.................26, 32, 33
Ann Arbor R. R. (Toledo & Ann Arbor)..75, 87, 88, 105, 122, 136
Ants, work of.................... 170
Apatite 219
Appalachian uplift................ 137
Aragonite................204, 205, 219
Argillaceous matter. See CLAY.. 40
Arkona Lake and Beach, 114, 138, 139, 142, 143, 153, 154, 195
Artesian wells................ ... 194
Asam, Joseph (claim 422)......192, 200
Ash Township (T. 5 S., R. 9 E.) 44, 54, 161 162
  Section 6.................. 195
  Section 8.................. 91
  Section 13.................. 56
  Section 20.................. 19
  Section 29................5, 56
  Section 30.................. 127
  Section 32.................. 56
  Section 34.................. 93
Ash tree......................164, 165
Aspen........................... 165
Asphaltum. See CARBONACEOUS and BITUMINOUS matter.. 219
Atrypa reticularis................ 227
Azalia 108, 122

B.

Balsam tree...................... 165
“ **Bastard** ” limestone..........61, 100
  See OÖLITE.
Battle of the Raisin.............. 6
Bay Creek..............9, 98, 100, 114
Beach levels..................... 109
  See also ARKONA, BELMORE, FOREST, GRASSMERE, LEIPSIC.
Beans production of.............. 163
Becraft limestone..............37, 228
Bedford Township (T. 8 and 9 S. R. 7 E)....14, 18, 141, 161, 162, 163, 196, 225
  Section 1.................. 98
  Section 2.................. 127
  Section 3.................. 214
  Section 4.................. 20

- **Bedford Township**
  - Section 10...............61, 99
  - Section 12.................. 98
  - Section 15............98, 99, 116
  - Section 16.................. 99
  - Section 21................99, 214
  - Section 29.................. 70
- **Bedrock**......................... 25
- **Beech**........................164, 165
- **Beet** sugar...............163, 178, 179
- **Bell, Robert**.................. 192
- **Bell, William**.................... 197
- **Bellaire**.......................... 186
- **Belmore Beach**...... 119, 136, 137, 138, 154, 196
- **Berlin Township** (T. 5 and 6 S. R. 9, 10 and 11 E.)....18, 53, 67, 92, 161, 162, 196
  - Section 1........... 56, 67, 92
  - Section 7...............56, 195
  - Section 8..............55, 56
  - Section 10.................. 123
  - Section 15.................. 201
  - Section 17................. 56
  - Section 18.................. 56
  - Section 19.................56, 214
  - Section 23.................. 113
  - Section 26.................. 56
  - Section 33........ 23, 70 152, 201
- **Big Sink**......................115, 116
- **Bitternut**....................... 165
- **Birmingham**, Wayne Co.......... 135
- **Bischof**.......................... 51
- **Bituminous** matter. See ASPHALT and CARBONACEOUS matter..............14, 29, 35, 46
- **Black River**...................... 135
- **Black** shale. See SAINT CLAIR shale.................... 25
- **Blissfield**........................ 139
- **Blouch, Thomas**................. 98
- **Bog** iron ore......... 24, 214, 215, 219
- **Bond, Oliver S.**.................. 70
- **Bondie, A.**....................... 201
- **Borrow, J.**....................... 56
- **Boyer, Edward D.**................ 180
- **Brachiopods.** See also names of genera.................. 56
- **Brancheau**....................... 92
- **Branch, Harmon**................. 197
- **Branner, J. C.**...............58, 170
- **Brazil**........................... 170
- **Brecciated** limestone....14, 47, 63, 94
- **Brest**...9, 10, 13, 18, 23, 61, 69, 128, 131, 135, 187, 207, 216, 217
- **Brick**..........................9, 187
- **Bridgeport**...................... 186
- **Brightbill Bros.**.................. 195
- **Brown, J.**........................ 178
- **Brown, George M.**............... 70
- **Brownstown**.................135, 196
- **Brunell** cited..................26, 28
- **Bryozoa**........................ 64
- **Buchanan**...................... 41
- **Buckeye**......................... 165
- **Buckwheat**, production of........ 163
- **Bullock, B. E.**.................75, 175
- **Bush Nelson**...................... 61
- **Butler, M.**........................ 98

C.

- **Calamites**, occurrence of.......... 29
- **Calcite**...9, 26, 42, 80, 89, 188, 198, 203, 208, 212, 219
- **Calcium** carbonate. See CALCITE, TRAVERTINE, TUFA and ANALYSES........42, 182, 188
- **Calcium** sulphate. (See ANHYDRITE, GYPSUM and ANALYSES.)
- **Caldwell Thomas**................ 86
- **Campbell Charles**............... 195
- **Canada.** See ONTARIO........... 12
- **Canandaigua**..................... 184
- **Carbonaceous** matter. (See also BITUMINOUS)....18, 67, 81, 89, 94, 95
- **Carleton**.......................24, 108
- **Carman, Louis**................. 78
- **Carr, George**.................... 99
- **Cartwright**...................... 92
- **Cass**.......................... 3, 136
- **Caudagalli** grit.................. 36
- **Caustic** soda. (See SODA ASH).... 15
- **Cavern** fauna.................... 117
- **Celery**, soil for.................. 172
- **Celestite**.......9, 80, 208, 209, 212, 219
- **Cement** materials.............180, 183
- **Chalybeate** springs.............. 213
- **Chamberlin, T. C.**............... 129
- **Champlain** epoch................ 132
- **Chara**.......................... 199
- **Chautauqua County**............. 147
- **Chattermarks**.................. 129

Chemung ... 28
Cherry ... 165
Chert 41, 76, 77, 82, 90, 97, 129, 216, 217, 219
Chestnut ... 164, 165
Christiancy, Judge J. P. ... 71, 160
    Quarries ... 37, 75, 178
Church & Co. ... 16, 201
Cincinnati anticline ... 74, 191
Cinnebar ... 215
Claims, French ... 119
    (see number of claims and names of owners.)
    21 ... 22
    64 ... 94
    65 ... 96
    88 ... 96
    160 ... 198
    161 ... 200
    230 ... 61
    275 ... 53
    408 ... 53
    422 ... 200
    428 ... 83
    436 ... 98
    472 ... 196
    484 ... 54
    493 ... 54
    494 ... 53
    498 ... 61, 95, 97
    516 ... 82
    520 ... 200
    521 ... 200
    528 ... 23
    529 ... 23, 93
    530 ... 23
    531 ... 23
    532 ... 61
    538 ... 61
    653 ... 113
    673 ... 198
    683 ... 84
    685 ... 83, 84, 198
Clarke, J. B., cited ... 29, 30, 31, 37, 44, 227
Clay ... 19, 20, 24, 39, 94
    uses of ... 152, 154, 183, 188, 215
Cleveland shales ... 25, 28
    Moraine ... 134, 143
Cliff, limestone. See DUNDEE ... 36
Climate ... 101, 104, 105, 160, 163, 194
Clover ... 162, 172
Coal ... 126
Concretions ... 26
Cone Station, Elevation of ... 108
Cone-in-cone " structure ... 27
Conglomerate ... 40, 48
Conocardium ... 226, 227
Contour lines ... 106
Conularia ... 226
Corals ... 40, 56, 226
Corbin, Byron J. ... 71
Cordier ... 48, 49
Corn ... 163
Corniferous. See CHERT and DUNDEE LIMESTONE.
Cosgroy, J. ... 119
Cotton wood ... 165
Cousino, Peter, misprinted Cushino ... 199
Cousino, S. B. ... 98
Cowles, W. H. ... 57, 187
Cramer, W. D. ... 16
Cranberry marsh ... 156
Crayfish, Effect of, on soil ... 170
Crapo, S. T. ... 91
Crinoids ... 225
Crosby, W. O. Cited ... 152
Crushing strength of Woolmith stone ... 175
Crusher for road metal ... 79, 185
Cummins, Morris, Quarry of ... 88, 115, 151

D.

Dalton, H. S. ... 16
Dalmania selenurus ... 227
Daly, R. A., cited ... 27
Dana, J. D., cited ... 49, 216, 217
Daniels quarry ... 225
Darton, N. H., cited ... 228
Darwin, Chas., cited ... 169
Daubrée ... 58
Dauncy, G. W. ... 195
Davis, Nelson, quarry of ... 13, 55, 85, 86, 88
Deep well records ... 66, 191
Deerfield ... 201
Defiance, Ohio and moraine ... 133, 143
Delray ... 46, 54
Dentons ... 139
Deposits. See under various formation names.
Detroit, city of ... 6, 52, 54

Detroit, river..................5, 16
moraine.............135, 143
Stone and Supply Co..47, 185
Detroit and Lima Northern R. R. 75, 79, 109, 176
Devonian = Devonic. See also DUNDEE, SAINT CLAIR and TRAVERSE.18, 25, 28, 37, 192, 228
Diluvium. See also DRIFT and TILL..................11, 12
Dip............. 10, 32, 45, 79, 87, 93
Disruptive gouges............... 129
Dobberstein, Augustus, well of... 56
Dogtooth spar. See CALCITE.... 204
Dolomites....46, 47, 49, 51, 59, 67, 68, 70, 73, 92, 94, 97, 99, 176, 180, 183, 186, 206, 212, 219
Donnelly, Peter.................. 204
Doty, E. B....................... 22
Drift. See TILL........19, 31, 38, 44
Dryer.......................... 133
Drought effect on wells........... 194
Dunbar, William................ 99
Dundee. See also CORNIFEROUS and UPPER HELDERBERG.
Chert beds................. 42
Deep well.........45, 72, 74, 192
limestone..38, 40, 75, 76, 78, 140, 174, 177, 191, 216, 228
Quarries......39, 75, 77, 175, 226
Township (T. 6 S., R. 6 and 7 E.)...9, 19, 20, 24, 31, 36, 37, 38, 71, 108, 113, 139, 152, 162
Section 8.................. 19
Section 15.................. 153
Section 16.................. 153
Section 18.................. 153
Section 21.................. 153
Section 22.................. 153
Section 25................ 72
Section 26..............19, 153
Valley in rock surface...... 122
Duval, Eli P............. 200

E.

Earthworms, effect on soil........ 169
Eaton, Chas. G................... 190
Elder bush....................... 165
Elevations. See ALTITUDES.
Elm............................ 165
Emerson, Mrs. Mary, oölite on farm of.................61, 93
Emmet County........... 14
Eposmite (Epsom salts)....71, 210, 219
Erie ice lobe..................124, 130
Lake......... 8, 13, 106, 108, 208
marsh.................145, 199
shale. (See ST. CLAIR SHALES.)
Township (8 and 9 S., 8 E.) 18, 161, 162, 183, 192, 194 196
Section 22...........70, 192, 199
trough of rock surface...... 124
Erigan River.... 123
Eureka Iron & Steel Works...... 15
Everett, Clayton................ 200
Exeter Township (T. 5 S., R. 8 E.)
Section 1.................. 195
Section 3.............123, 195
Section 18.................. 123
Section 29. See WOOLMITH QUARRIES.............54, 78

F.

Farm products................159, 162
Favosites......................48, 227
Federman, altitude of............ 108
Fenestella.......... 227
Ferguson, Misses J. and N....... 99
Ferretto......................... 126
Findlay, Ohio............133, 134, 191
Fishes................40, 117, 222, 227
Flat Rock.. ....14, 91, 112, 113
Flood plain. 11
Foerste, A. F., cited............. 192
Forchhammar.................30, 51
Ford, B. R....................... 34
Forest Beach..18, 105, 114, 139, 140, 141, 143, 154, 171
Fort Wayne, Indiana............. 143
Fossils..34, 92, 93, 97, 99, 137, 220, et seq.
Fracastoro....................... 220
French, W. T., cited............. 164
French occupancy............5, 6, 119
Frenchtown........ 6, 23, 94, 161, 162
quarries.................... 22
Twp. (6 and 7 S., R. 8, 9 and 10 E.) See also CLAIMS and RAISIN RIVER.....94, 161, 162
Frey, John...................... 70
Frost, date of.................... 101
Fruit culture.............101, 160, 161

Fucus vesiculosus............... 30

G.

Gaffney, Hugh.................... 175
Gas................33, 34, 70, 190, 193
Gashing.......................... 85
Gasteropods.............56, 79, 86 226
Genesee shale. See ST. CLAIR shale...................27, 32
Geodes. See also CHERT......... 11
Geological Surveys; for references to see names of various authors, i.e., for Ohio, ORTON, GILBERT, NEWBERRY, WINCHELL, N. H.; for Michigan, HIGGINS, HOUGHTON, HUBBARD, WINCHELL, A., ROMINGER, LANE; for U. S., IRVING, LEVERETT, TIGHT; for Indiana, DRYER.
Gibraltar......................54, 91
Gilbert, G. K. cited, 5, 140, 141, 146, 147
Gilmore, Q. A. cited............. 175
Glacial Epoch.............39, 120, 124
Glacial striæ. See STRIÆ........ 129
Glass sand. See SYLVANIA sandstone...9, 11, 55, 84, 86, 88, 186
  seams..................... 81
Glœcapsa and Glœthece.......... 65
Goodells......................... 140
Grade of county and railroads. See ALTITUDE............ 106
Grafton, altitude of.............. 108
Grape wild...................... 160
Grape P. O....53, 56, 101, 104, 113, 176
Gravel.................19, 20, 110, 153
Grassmere Beaches...141, 143, 154, 171
Great Salt Lake..............64, 66
Great Sulphur Springs (near Erie) 199
Greening Bros................... 196
Grosse Isle....................91, 135
Guelph dolomite................. 72
Gypsum..........13, 46, 50, 52, 178, 209

H.

Hadley, Walter K................. 91
Halfway Creek...........114, 131, 146
Halite (salt)..................211, 219
Hall, I. R. cited................. 36
Hall, Edmund.................... 54
Hamilton. See TRAVERSE..14, 22, 23, 27, 31, 186
Harmon, James................... 196
Harris, E. E...................... 70
  Line...... 6
  Ville....................... 140
Haw............................ 165
Hays........ 168
Heath........................... 182
Heck, Charles.................... 98
Helderberg strata. See DUNDEE and MONROE beds......14, 37
Heliophyllum.................... 227
Hercules Cement Co............. 180
Herkimer, Robert C.............. 190
Hershey......................... 23
Hickory.....................164, 165
Higgins, S. W...................9, 137
Highlands of the Hudson, a possible lake barrier.......... 137
Hillsdale County................ 22
Historical notes........3, 112, 147, 160
Hoffman, John................... 82
Hogtooth spar...................9, 204
Holland, Ohio.................... 128
Houghton, Douglas.....9, 10, 187, 207
Hubbard, Bela..9, 10, 11, 23, 128, 130, 137, 138, 157, 158, 180, 186, 200, 207, 214
Hubbard, L. L................... 15
Hudson river group.........11, 72, 74
Hunter.......................... 41
Hunt, T. S............48, 50, 51, 52, 228
Huron Lake..................135, 137
  River. 23, 112, 113, 135, 145
  Shale.......... ...13, 14, 25, 28
  Township.................. 126
Hydrogen sulphide...194, 199, 212, 213

I.

Ice sheet. See GLACIAL EPOCH and ILLINOIAN, IOWAN and WISCONSIN ice sheet.
Ida quarries....14, 87, 88, 174, 177, 207
  Twp. (T. 7 S., R. 7 E.)...18, 19, 20, 21, 54. 108, 122, 161, 162
  well deep (Sec. 3).........54, 70
    Sec 4.... ....55, 85
    Sec. 15............. 56
    Sec. 16.............. 55, 117
Ilgenfritz Nursery Co........... 157

Illinoian ice sheet....23, 126, 127, 130
Imlay............................ 143
Indian occupation.............. 5
Indiana geology referred to. See Tight, Leverett, Taylor..................... 133
Ingersoll, R...................... 153
Inlet creek into Ottawa lake.. 91, 131
Iowan ice sheet..............126, 130
Iron ore and oxide..10, 30, 39, 197, 215
Iron pyrite. See Pyrite.
Irving........................... 58

J.

Jacobs, Charles.................. 190
Jacobson, cited.................. 41
Jackson County...............22, 183
Jefferson County................ 147
Jasper, conglomerate............. 20
Johnson, cited.................... 158

K.

Kallman, Herman, cited......... 175
Kane, Frank...................... 90
Kelley, W. J...................... 200
Kelley's Island..... .... 130, 147
Kettle Point (Lake Huron)........ 28
Kilns. See also Lime and Brick 91, 175, 178
Kingstone's Mills................ 32
Kirschmeier, G. A., cited......... 76
Knaggs, John...................... 83
Knapp, Christopher.............. 20
Kring, S. A........ ....82, 176

L.

Labeau, Richard.................. 93
Lake. See other part of names, e. g., Huron, Erie, Warren.
Shore R. R...85, 92, 106, 108, 186
Ridge. See Belmore Beach. 10
See also Marl, Marsh and Sink.
Lambertville..........19, 70, 114, 196
Lamellibranchs...............56, 226
Lane, A. C....26, 32, 40, 66, 72, 73, 109, 141, 142, 228
LaSalle P. O. Station and township. (T. 7 S., R. 8 and 9 E.) 18, 54, 97, 98, 108, 161, 162, 183
Sec. 20........................ 98
Sec. 29........................ 98
Sec. 32.................. 61, 98
Sec. 33........................ 98
Leipsic Beach........133, 134, 136, 143
Lenawee Co..........3, 22, 25, 137, 201
Junction.................... 136
Leonard, O. W................... 189
Leperditia alta........... 43, 80, 225
Lepidodendron ,................. 29
Leverett, F........... 23, 126, 133, 134
Lime. See Kilns.......... 9, 175, 179
Limestone. See also Calcite, Brecciated limestone, and Dundee limestone and Analyses..9, 11, 12, 13, 15, 22, 26, 33, 39, 40, 48, 112, 179, 181, 182, 184
Lithology and lithographic characters and history
of St. Clair shales 29, 35, 40
of Traverse group........35, 40
of Dundee group............ 40
of Monroe group............ 46
Little Traverse group=Traverse 13, 14, 31, 40
Little Lake..14, 61, 63, 65, 98, 224, 225
Little Sink....14, 96, 114, 174, 207, 208, 224, 225
"**Liver Rock,**" mottled Dolomite which see 66
Livingstone Co................... 113
Livonia Twp...................... 137
Loam. See Soil................. 155
Lockwood, Ezra...... 17, 19, 117, 170
London Twp. T. 5 S., R. 7 E.. 9, 19, 20, 37, 161, 162, 188
Sec. 7....................... 34
Sec. 16...................... 87
Sec. 20...................... 19
Long, John 20
Loranger, C. B...... 50
Lotus bed and house.......... 148, 197
Lower Helderberg. See Monroe and Helderberg..13, 14, 15, 44, 48, 225, 227

Lower Pentamerus=Kingston 37, 43
Lucas Co......... 128
Lulu P. O. and quarries....14, 55, 78, 87, 88, 108

M.

McCarthy, Jacob........ 78
McDermott, Prof., cited........ 81
Mackinac........ 28, 137
McMullen, Samuel........ 34
McQuarrie quarries........ 91
Macon River..6, 13, 19, 38, 71, 111, 113, 131, 132, 176, 189
  Quarries. See CHRISTIANCY quarries..39, 77, 175, 226
Magnesia. See ANALYSES.. 178, 180
Magnesium carbonate. See DOLOMITE........ 42
  sulphate. See EPSOMITE... 71
Manlius limestone. See MONROE beds........ 37, 228
Maps........ 7, 10, 16, 17, 137
Maple tree........ 164, 165
Marcasite........ 26, 30, 213, 219
Marcellus shale........ 27, 33
Marl......10, 24, 182, 183, 200, 201, 219
Marine vegetation........ 29
Marselli........ 221
Marshall sandstone........ 13, 22, 23
Maschke, cited........ 41
Matia........ 49
Matthes, August G......... 190
Maumee Lake and Beach..133, 135, 137, 138, 143, 153
Maumee (= Miami) **River** and **Valley**........8, 89, 133, 215
Maybee........ 108
Medina sandstone........ 73
Megambonia........ 225
Merista and **Meristella**........ 223
Merrill, Geo. P., cited........ 150
Metal, road........ 97
Meyers Bros........ 189
Miami=Maumee.
Michigan Central R. R......... 106, 108, 109, 185, 186
Michigan Stone & Supply Co.....16, 79
Michigan White Sand Co......... 186
Milan Brick and Tile Manufacturing Co......... 189
Milan Township (T. 5 S., R. 6 E.) 17, 19, 20, 24, 25, 26, 108, 122, 136, 139, 142, 161, 162 195
  Section 1........ 189
  Section 2........122, 189
  Section 3........20, 34, 122
  Section 4........19, 122
  Section 5........34, 164
  Section 6...19, 109, 136, 164, 195
  Section 7........122, 164
  Section 8........122, 164
  Section 9........19, 34, 122
  Section 10........ 214
  Section 14........ 34
  Section 17........ 34
  Section 18........34, 122
  Section 20........19, 196
  Section 21........ 214
  Section 22........ 34
  Section 23........ 214
  Section 26........34, 214
  Section 27........ 195
Milhahn, F......... 84
Minerals. (See names of minerals) 203
Mitchell map........ 7
Modiolopsis dubius........ 224
Mohawk Valley, outlet for lakes.. 137
Molasses, beet sugar........179, 207
Molluscs........ 155
Monclova, Ohio........ 128
Monguagon Township. See TRENTON........12, 135
Monroe beds....36, 43-74, 122, 174, 216, 222, 228
Monroe brickyard........142, 190
Monroe, City of... 9, 10, 18, 40, 47, 52, 93, 108, 112, 113, 138, 162, 164, 190, 207, 208
Monroe County, general facts...1, 14, 25, 39, 107, 127, 161-164, 183
Monroe marsh........ 145
Monroe Stone Co.....17, 47, 94, 96, 131, 185, Plate IV
Monroe well........15, 44, 46, 74, 192
Monroe Township 6 and 7 S., R. 8 and 9 E. (mainly occupied by French claims, see CLAIMS)........ 161, 162, 183
Montgomery, E......... 116
Moraines........23, 127, 133-143
Morrison, J. M......... 123

Morocco, Station, Alt. of......... 108
Mouillie Creek, marsh and pond.. 145
Muck.........................155, 156
Mud cracks...................... 47
Mulberry....................... 165

N.

Namet Cybi....... ....6, 160
Nautilus........................ 227
Navarre, quarries.........61, 174, 216
  Alexander T.........95, 97
  Adeline A............. 199
  Dennis...............61, 97
  Mary T................ 95
  Patrick................ 97
  Francis................ 6
Neumayr, E., cited................ 49
Newberry, J. S., cited..25, 28, 36, 43, 60
Newport........9, 69, 92, 108, 135, 185
  quarries................ 92
  well.................... 67
New York, comparison with series of.......28, 30, 37, 44, 228
  Geological Survey. See also HALL, CLARKE, SCHUCHERT.
Niagara River.................. 144
  Formation......... 73
Nichols, Christopher....... 198
Nicols, John and well..........84, 86
Nims, C. S...................... 72
Nipissing Great Lake.........144. 147
Nitrogen in soils 166, 167, 168, 172, 173
Noble-Moore well at Monroe...47, 66, 74, plate V.
Nogard well.........71, 72, 74, 75, 77
Nolan, Patrick.................. 34
Northwest Territory............. 7
Northville...................... 133
Nucleospira roundata............. 223

O.

Oak............................ 164
Oakland County.................. 137
Oats............................ 162
Ochre............ ....214, 219
Ochsenius....................... 210
O'Conner, M. E................... 70
Ogle, Geo. A..................... 17
Ohio....8, 22, 31, 38, 45, 73, 74, 186, 191
  Geological Survey. See NEWBERRY, ORTON, WINCHELL, GILBERT.
Oil........................32, 39, 190, 193
Ohio Shale. See ST. CLAIR shale. 25, 26, 28
Olentangy shale.................. 31
Onondaga strata............13, 37, 43
Ontario..........20, 23, 26, 33, 186, 191
Onychodus....................... 227
Oolite..11, 13, 14, 46, 51, 60, 63, 65, 66, 79, 83, 84, 86, 93, 97, 99, 206
Oriskany sandstone............14, 60
Orthis.......................223, 226
Orthoceras...................... 227
Orton, E.....25, 29, 39, 44, 73, 130, 192
Ottawa Indians.................. 6
Ottawa Lake....13, 14, 16, 18, 47, 60, 90, 108, 117, 120, 131, 174, 176, 190, 225
Ottawa Lake Quarries.........89, 132
Otter Creek........13, 61, 114, 197 199
Oxbows.......................112, 113

P.

Palaeolithic man................ 5
Palmer, G. W..................... 123
Papaw........................... 165
Paragon Polishing Powder....... 200
Paracyclas elliptica............. 227
Patrick Quarry... 47
Peat...................10, 24, 156, 157
Pebbles accumulation of. (See BOULDERS)........ 153
Pennock, J. D., cited............. 83
Pentamerus...................... 224
Peppermint...................... 172
Pere Marquette.......98, 108, 109, 186
Petersburg......19, 37, 38, 78, 108, 112
Peters, Chas. G................56, 59
  John..................... 78
Petrolea..................32, 38, 39
Petroleum. (See OIL and GAS... 27
Pewamo channel..............141, 143
Phacops......................... 227
Phillipi, E., cited on dolomite.... 50
Pignut. 165
Plants, fossil.........29, 65, 81, 84, 226
  list of trees.............. 165

Plants, of sand ridges. (See also chapter on soils and subsoils)..111, 118, 141, plate XI
Plaster. (See ANHYDRITE and GYPSUM).................. 209
Platyceras........................ 226
Pleistocene=Quaternary......... 72
Pleuronotus enos..... 214
Plemodore, Enos 214
Plum Creek....9, 13, 14, 47, 61, 62, 63, 69, 95, 97, 110, 112, 114, 131, 151, 174, 175, 185, 207, 213, 216, 224
Plymouth, Belmore Beach at..136, 137
Point aux Peaux...23, 61, 93, 128, 130, 131, 144, 207, 208, 216, 217
Point Mouillée.................. 145
Polypora..................... ... 227
Poor farm....................... 107
Poplar (popple)...............164, 165
Population......................3, 7
Pontiac, moraine, near........... 136
Portage, strata.............. 28, 33
Port Huron moraine.............. 143
Portland cement. See CEMENT.
Potatoes, production of.......159, 163
Postglacial deposits.............. 24
Postglacial disturbance.......... 147
Pottawatomies.................. 6
Potter, F. C., and his well .70, 74, 192
Precipitation..........101 to 105, 164
Presque Isle County............. 14
Proteus......................... 227
Pterinea Aviculoides............. 225
Pulver, Horace, quarry....... 37, 77
Putnam, R. R.................... 16
Pyrite. See SULPHUR....26, 213, 219

Q.

Quarries. See names of owners and chapters thereon.
Quartz....................84, 217, 219
Quartzite....................... 58
Quaternary formations. See GLACIAL epoch.............. 18
Quicksand...................... 19
Quicklime. See also LIME....... 175

R.

Rabideu, Daniel..............89, 117
Railroads. See also names, viz., ANN Arbor=Toledo and Ann Arbor, DETROIT and Lima Northern, LAKE Shore & Michigan Southern, PERE Marquette=Flint & Pere Marquette, WABASH.............1, 2, 108
Raisin River....6, 9, 16, 38, 82, 83, 94, 96, 108, 110, 112, 145, 160, 186, 196
Raisinville Township (T. 6 and 7 S., R. 7 and 8 E.; this township is mainly covered by French claims. See CLAIMS..14, 24, 44, 53, 60, 122, 151, 161, 162, 175, 208
  Sec. 8................ 72
  Sec. 26................6, 7, 84
  Sec. 8...................... 72
  Sec. 26........... 84
Raisinville quarries............. 82
Ramsey...................... 48
Rath, Fritz, and quarries...66, 83, 86
Rea............................ 108
Redgrave, cited on cements....... 182
Retzia formosa.................. 224
Rhizocarps...................... 29
Rhyncospira formosa............. 224
Ridges. See LAKE, RIDGE and BEACH.................... 110
Ridgeway....................... 136
Rivers. See names of.......108 to 111
Road metal....................97, 183
Robinson, Samuel................ 215
Robinson and Taylor............ 82
Rock surface topography......... 120
Rock salt. See HALITE........47, 201
Rockwood town and well..145, 190, 202
  South..........108, 114, 123, 201
Rominger, Carl......14, 27, 28, 36, 43, 86, 87, 116, 186, 222, 225
Ross, DeForrest.................. 16
Rothpletz, A..................... 65
Royal Oak....................... 32
Russell, I. C..................... 64

S.

Saginaw Lake................... 140
Saint Clair River................5, 32

Saint Clair County............... 148
  Lake....................... 146
  Shale (Genesee shale)....11, 15, 25, 26, 33, 37, 149, 201
Salina....................13, 52, 72, 228
Saline.........................9, 111
Salt.......................15, 47, 201
Salt springs....................9, 201
Salt water 193
Samaria, elevation of........... 108
Sand.......20, 24, 58, 59, 77, 81, 92, 105, 139, 152, 153, 166
Sandrock and sandstone....11, 14, 34, 56, 87, 88
Sanford, Charles................ 34
Sarnia........... 26
Sassafras....................... 165
Saylor, C. F., cited.............. 164
Schiavo......................... 221
Schoharie grit.................. 36
Schuchert, C...........37, 44, 227, 228
Scofield..... ....108, 195
Scratches. See STRIÆ.......... 10
Sea water......................41, 49
  weed.........................30, 81
Selenite.............67, 69, 72, 209, 219
Shadbush.................... ... 165
Shale. See GENESEE, ST. CLAIR & TRAVERSE....12, 27, 33, 48, 70
Shaler, N. S..............167, 170, 215
Sharkey, Edward.............197, 199
Sharks......................... 40
Sherzer, W. H................80, 227
Shawnee Spring................. 197
Sibley Quarry. See TRENTON.... 16, 39, 75, 77, 129, 177
Siderite........................ 26
Silica. See ANALYSES........... 41
Silicious dolomite..............90, 92
Silt............................24, 155
Sink holes....................114-116
Sissung, Henry G. and quarry..93, 131
Slaking of various limes.......... 177
Smith, G. F....................16, 218
  Mrs. Lizzie................. 93
  William.................... 221
Smyth, C. H., cited.............. 57
Snails.......................... 155
Snowfall........................ 101
"**Soapstone**"=calcareous shale.33, 34
"**Soda ash**"=sodium bicarbonate 15, 177
Soils.....................149, 157, 160
Sorby, cited...................... 57
Sorter, Catherine............... 198
  Elisha........ 99
South Bass Island............... 128
Southern Chemical Co............ 176
South Rockwood.... 108, 114, 123, 201
Spada........................... 221
Spalding flour mill, Rock near.... 78
Servis.......................... 12
Sparks & Allen................. 72
Spencer J. W................139, 140
Sphagnum...................157, 198
Spink, E. E.................... 34
Spirorbis....................... 80
Spirifer................ 223, 226, 227
Sporangites..................... 29
Squash, Production of............ 163
Statistics.. 4, 7, 103, 104, 105, 159, 161, 162
Steiner, Elevation of............ 108
Stewart farm.................... 78
Stictopora...................... 227
Stone. See ROAD metal, LIMESTONE, SANDSTONE, QUARRIES, etc.
Stone roads...................... 184
Stony Creek....9, 61, 63, 64, 65, 93, 108
  Point.. 23, 61, 63, 93, 99, 130, 131, 135, 136, 144, 175, 207, 208, 216, 217
  Ridge......... 105, 142, 147, 175
Storms, effect of, on wells........ 195
Stout, Katherine................ 190
Strasburg....................... 108
Striæ..............10, 23, 130, 131, 132
Strobel......................... 56
Strophodonta............... 226, 227
Stromatopora............ 64, 79, 227
Strong, Frank............... 22, 187
Strong, John 16, 190
Strontianite.... 9, 85, 89, 205, 206, 209
Strontium. See also STRONTIANITE and CALCITE.. 85, 179, 307
Stumm, Peter.................... 56
Stylolites....................... 89
Subsoil. See chapters v. and vi.. 152
Sugar beet, Climate and soil for 104, 163, 164, 179, 207
Sullivan, Nora.................. 84
Sulphates 26, 30

Sulphuric acid and soil........... 167
Sulphur..80, 194, 197, 200, 208, 212, 219
Island........................ 26
waters................ 212, 213
Sumach................................ 165
Summerfield Twp. (T. 7 S., R. 6 E.,) 19, 24, 44, 114, 123, 139, 161, 162, 170, 214
Sec. 4.................. 20, 78
Sec. 6 139
Sec. 7 .... 20, 190
Sec. 18.................... 139
Sec. 19..................... 214
Sec. 21..................... 139
Sec. 24......... 54, 156, 157, 200
Sec. 25..................... 214
Sec. 27..................... 20
Sec. 31..................... 78
Sec. 34..................... 190
Sec. 36 (T. 6 S., R. 6 E.)..... 107
Sundstrom, K. J............... 76, 94
Suzore, Peter.................... 94
Swan Creek.................. 9, 114
Sycamore........................ 164
Sylvania........... 13, 24, 55, 87, 140
sandstone (glass sand).. 14, 15, 16, 44, 60, 69, 70, 81, 91, 92, 97, 151, 174, 186, 206, 214, 228

T.

Taft, J. M., well of.............. 195
Tamarack Creek................ 61
Taylor, F. B., cited..127, 134, 136, 161, 146
Temperance.................. 23, 108
Temperatures................105, 163
Tentaculites...................... 227
Tertiary clays.................... 12
Thickness of strata..18, 26, 28, 32, 38
Thomas, B. W.................. 29
Thornbush....................... 165
Thunder Bay.................... 26
Tile.........................187, 190
Till. See DRIFT, BOULDER, CLAY. 19, 152
Titanic oxide.................... 68
Titles, Indian................... 6
Todd, Charles.................. 195
Toledo............7, 74. 101 to 105, 161
Moraine...............135, 143
Toledo & Ann Arbor R. R. See Ann Arbor R. R.
Townships. See locations under names of townships, viz., ASH, BEDFORD, BERLIN, DUNDEE, ERIE, EXETER, FRENCHTOWN, IDA, LA SALLE, LONDON, MILAN, MONROE, RAISINVILLE, SUMMERFIELD and WHITFIELD. Tabulations by townships are on pp. 4, 161, 162
Transportation of drift.....22, 23, 78
Traverse. See HAMILTON and MARCELLUS..15, 31, 33, 35, 37, 40, 122, 149, 191
Trematospira.................... 224
Tremolite......................9, 207
Trembly, Dr. J. B............... 105
Trenton (Monguagon.) See also SIBLEY QUARRY.......12, 23, 74, 130, 135, 177, 227
Trenton deep wells...........45, 201
Trenton limestone......70, 71, 72, 73, 191, 192
Trilobites.....................56, 226
Tufa, calcareous...........24, 198, 200, 205, 219
Tully limestone.................. 122
Tymochtee slate...............69, 73
Tyre............................ 136

U.

Ubly..........................136, 138
United States lake survey levels . 107
Geological survey. See GEOLOGICAL survey..107, 177, 186
Bureau of Agriculture...... 184
Upper Helderberg. See DUNDEE beds...............13, 14, 15, 36, 60, 228
Upper Monroe beds............... 122
Upper Pentamerus limestone..43, 228
Utica shales..................72, 74

V.

Valleys of present rivers.......... 111
the rock surface............ 121
Valrance, Howard.............. 56
Van Akin, Simeon.............70, 71

Van Wormer, John.............. 127
Van Wert stage and lakes.....133, 136
Vegetation. See PLANTS........ 40
Vesceliue, J. R.................... 195
Von Buch....................... 49
Vienna, altitude of...........108, 199
Vorster, Edward................ 180
Vosges.......................... 58

W.

Wabash R. R.................... 122
Wadsworth, M. E................ 15
Waldecker, Mathias............. 127
Waldheimia...................... 221
Walnut.......................164, 165
Warping, post glacial........... 147
Washtenaw County...........122, 127
Warren Lake and Beach..........
138, 140, 143, 153, 154
Waterlime group. See MONROE
beds 43, 44, 60, 72, 180, 225, 228
Water supply...................... 10
Water power...................... 112
Wayne County. See also SIBLEY
quarries, TRENTON, WYANDOTTE...3, 31, 122, 137,
138, 139, 196
Weathering...................149, 167
Welsh, Thomas.................. 9
West Sister island................ 128
Wethered, cited.................. 58
Wheat, production of............ 163
White, A. D...................... 12
White quarry (Little Lake)....61, 99
Whitehouse, O., striæ at.......... 128
Whittlesey Lake.....136, 138, 143, 153
Whiteford quarries............... 100
Whiteford Township (T. 8 and 9
S., R. 6 E.)...18, 22, 44, 53,
53, 114, 121, 123, 139, 161,
162, 185
  Section 2.............55, 88, 114
  Section 4.................61, 100
  Section 5.................. 53
Whiteford Township Section 7. 89, 91
  Section 8.................89, 117
  Section 10...........89, 117, 119
  Section 11.................. 117
  Section 19................91, 116
  Section 25................61, 100
  Section 27.................. 22
  Section 28................53, 54
  Section 29.................. 53
  Section 32................53, 54
  Section 33.................. 53
Whitfield, R. P...............222,-225
Whitfieldella..................... 223
Wilcox, Byron................... 87
Wilcox, Homer..........177, 180, 183
Wiley, on sugar beet industry. 164,
179, 207
Wilkerson, A..................... 71
Williams, H. S., cited............ 227
Willis, C.......................... 99
Willow Run................. 55, 97
Winchell, A...12, 13, 22, 23, 25, 26,
31, 36, 43, 101, 118, 128, 130,
172, 175, 180, 186, 214, 216, 217
Winchell, N. H................ 36, 73
Winds, Effect of.................. 154
Wisconsin ice sheet.......... 126, 127
Witchhazel....................... 165
Wolff, Emil, cited................ 158
Woolmith quarries.. 14, 54, 60, 66,
78, 81, 82, 91, 131, 151, 174,
176, 185, 194, 204, 208, 212, 218
Wright, C. E..................... 15
Wyandotte (Indian tribe)......... 6
  City of..... 15, 38, 46, 54, 73, 135

Y.

Young, William.................. 195
Young, Stephen.............. 61, 100
Ypsilanti........................ 133
Yuma............................ 176

Z.

Zaphrentis...................... 227

DESCRIPTION OF PLATE XVII.

Figs. 1—3. **Streptorhynchus hydraulicum. Whitf.**
" 4—5. **Spirifera Vanuxemi. Hall.**

" 6—7. **Meristella lævis. Van.**
" 8—10. " **bella. Hall.**

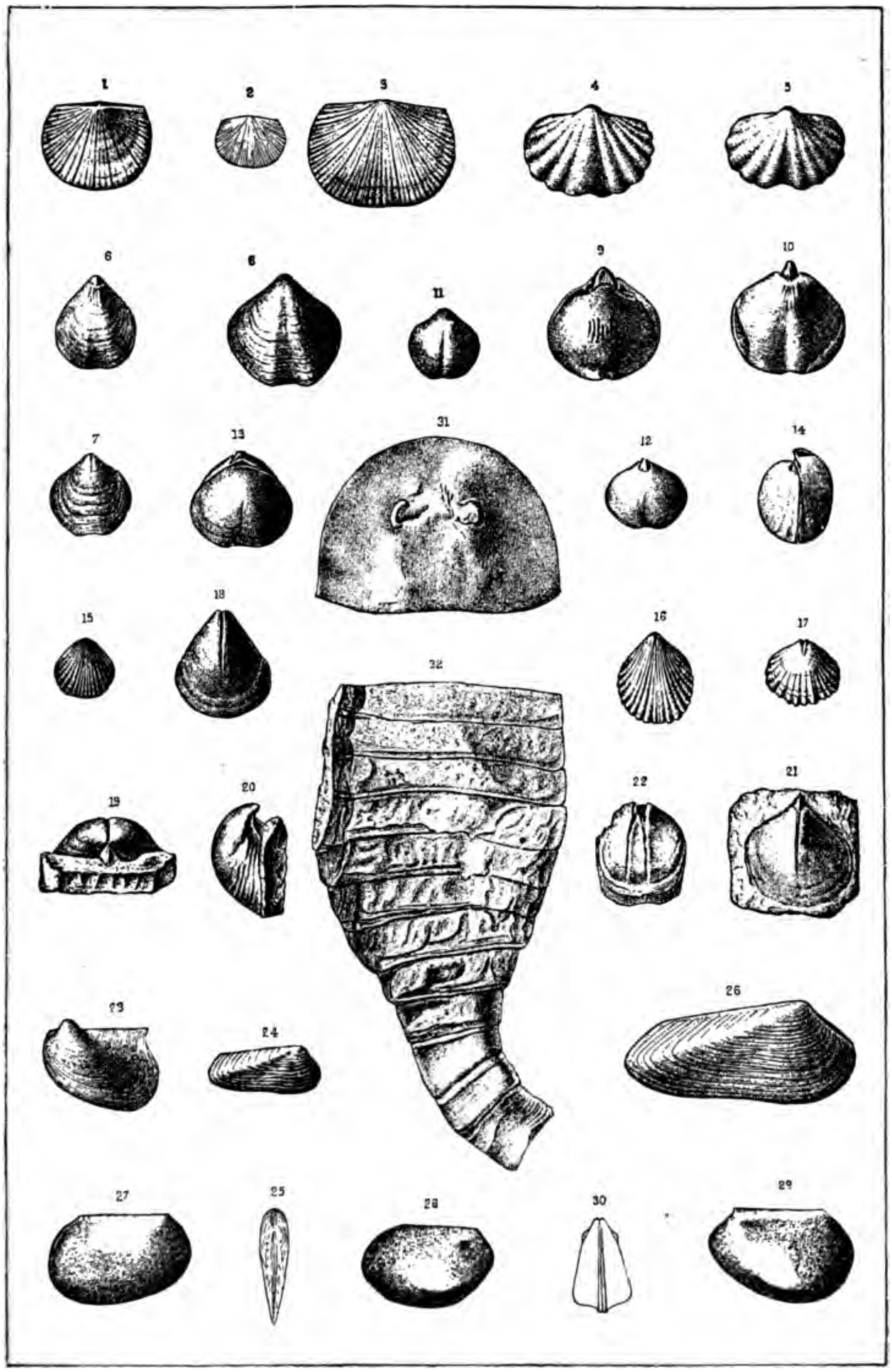
" 11—14. **Nucleospira rotundata. Whitf.**
" 15—16. **Retzia formosa. Hall.**

" 17. **Rhynchonella hydraulica. Whitf.**
" 18—22. **Pentamerus pes-ovis. Whitf.**

" 23. **Pterinea aviculoidea. Hall.**
" 24—26. **Goniophora dubia. Hall.**

" 27. **Leperditia alta. Conrad.**
" 28—30. " **angulifera. Whitf.**

" 31—2. **Eurypterus eriensis. Whitf.**
See pp. 223 to 225.



R. P. Whitfield Del

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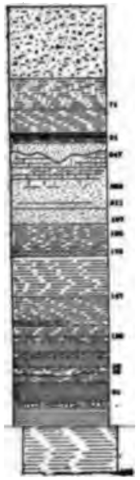
UNIV. OF

GEOLOGICAL COLUMN IN HURON COUNTY.

(Adapted so far as possible to a well 2270 feet deep at Caseville and one 1920 feet deep at Harbor Beach.)



CORRELATIONS.	NAMES.	TYPICAL EXPOSURES.	LITHOLOGICAL CHARACTER.	NOTES.
	PLEISTOCENE	Port Crescent White Rock Ubly	Lake sands, lake clays and till	Section very different in different localities. For fossils of shell marls see Chapter X
CARBONIFERIOUS CONGLOMERATE	JACKSON COAL MEASURES	Sebewaing coal mines and shafts	Black, white and blue shales, coal and sandstone	Distance from coal measures to Napoleon given by wells which start in Maxville limestone and run into it, *e. g.*, on Sec. 36, T. 17 N., R. 9 E., sandstone at 264'; Sec. 31, T. 17 N., R. 10 E. at 270'
LOWER KASKASKIA AND UPPER SAINT LOUIS	GRAND RAPIDS: Maxville	Bayport Shebeon Charity islands	Sandy yellow limestones, crossbeded white sandstone, little dolomite	*Lithostrotion canadense, L. proliferum. Allorisma clavata, A. elongata, Syringopora ramulosa, Spiriferina spinosa, Seminula argentea, Phillipsia longispina*
AND BURLINGTON	GRAND RAPIDS: Michigan		Light grey shale with gypsum and pyrite; salty blueish shales; argillaceous hydraulic limestones	Macpherson's well, Sec. 30, T. 17 N., R. 11 E., strikes bedrock at 40', but has no good water until 210', in white sandstone Leipprandt's well, Sec. 13, T. 17 N., R. 10 E.; gypsum at 55' and 100', Napoleon white sandstone at 228' Sec. 25, T. 17 N., R 9 E., plaster at 10' to 25', flow at 140' Gypsum is 155' above top of Napoleon at Midland, 110' at Alma, 140' at Bay City
— [illegible]	C	Soule Sec.24, T. 17 N., R. 11 E. Sec. 19, T. 17 N., R. 12 E.	Blue to black micaceous	*Spirifer forbesi* ?, *Productella arcuata* ? Thickness of Coldwater from base of Marshall to top of Berea shale, [illegible] (Harbor Beach), 845'+ (New River), 965?' Port Austin, 816' (Port Hope)
		Forestville		

Rest of column not exposed

CORRELATIONS.	NAMES.		NOTES.
BUENA VISTA FLAGS		108 feet (Harbor Beach)	Top, 999' Bottom, 1061' Harbor Beach, 1000' 1055' White Rock, 1020' 1060' Forestville, below the base of the Marshall
BEREA SHALE		75 feet	
BEREA GRIT		50 feet	
BEDFORD SHALE	OHIO OR SAINT CLAIR	3 feet	From base of Berea grit to top of Traverse (1120—664) 456 to (2270—1750 Caseville) 520 feet
CLEVELAND SHALE		133 feet	
ERIE SHALE		270 feet	15 feet very hard limestone at 1400', compare Alpena at 153' and Bay City at 2910 feet, Encrinal limestone?
HURON SHALE			
HAMILTON	TRAVERSE	605	95' more to bottom of Harbor Beach, well strong bitterns; see analyses
MARCELLUS			
CORNIFEROUS	DUNDEE,	119	Unexplored
SALINA	MONROE	2,000?	
NIAGARA		400?	Total to Trenton from base of Marshall, about 5000 feet

GEOLOGICAL SURVEY OF MICHIGAN

ALFRED C. LANE, STATE GEOLOGIST

VOL. VII

PART II

GEOLOGICAL REPORT

ON

HURON COUNTY

MICHIGAN

BY

ALFRED C. LANE

ACCOMPANIED BY ELEVEN PLATES AND TWELVE FIGURES
INCLUDING TWO COLORED MAPS

PUBLISHED BY AUTHORITY OF THE LAWS OF
MICHIGAN
UNDER THE DIRECTION OF
THE BOARD OF GEOLOGICAL SURVEY

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OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN, Sept. 15, 1900.

To the Honorable, the Board of Geological Survey of Michigan:

HON. HAZEN S. PINGREE, *President.*
HON. PERRY F. POWERS.
HON. JASON E. HAMMOND, *Secretary.*

GENTLEMEN—Herewith I transmit as Part II of Vol. VII, a report on the geology of Huron county, the Thumb of Lower Michigan. Like Part I, 500 copies are issued separately, while 1,000 are bound in the complete volume. Of Chapter IX, 100 copies have been printed for Prof. C. A. Davis, and the same number of § 2 and of § 3 of Chapter X for my co-adjutors Bryant Walker, Esq., and Mr. W. F. Cooper.

I trust this report may aid the residents and well drillers of the county in getting good water supplies, may save money in proving up the resources of the county in coal, gypsum, limestone, and grindstone, and may call attention to the probable value of the shale deposits. Just at the moment I notice items in the daily press concerning lead, a subject which I have also examined.

To my fellow geologists it may be interesting to see what can be done with the sub-surface geology, when outcrops are very rare, by means of records and tests of farmer's wells.

It will probably be of use to them also to have the Marshall of this region more fully treated, and a definite and detailed geological column made out, covering the dividing line between Devonian and Carboniferous.

I feel that I ought to call attention here as well as in the text to the important help which I have received from Messrs. Davis, Gordon, Walker and Cooper, whose names ought almost to have appeared on the title page, and also to the fact that the work of preparation of this report, though always in my charge, was largely done during the administration of my predecessor, Dr. Hubbard.

With great respect I am your obedient servant,

ALFRED C. LANE,
State Geologist.

TABLE OF CONTENTS.

CHAPTER I.

INTRODUCTION.

Page.
§ 1. Historical 1
§ 2. Previous geological reports, Houghton, Winchell, Rominger 2
§ 3. Recent work 5
§ 4. Acknowledgments 6
§ 5. Maps 7

CHAPTER II.

GEOLOGICAL COLUMN.

§ 1. Pleistocene, i. e., unconsolidated materials, soils and subsoils 9
§ 2. Coal measures of Sebewaing 11
§ 3. Maxville limestone of Bayport 12
§ 4. Michigan series 13
§ 5. Marshall series 16
§ 6. Napoleon or Upper Marshall sandstone 18
§ 7. Lower Marshall series 19
§ 8. Coldwater shales 24
§ 9. Formations not exposed at surface 27
Berea shale, Berea grit, Ohio, i. e., Bedford, Cleveland, Erie, and Huron shales, Traverse group and Helderberg limestones.

CHAPTER III.

PHYSICAL GEOGRAPHY OF HURON COUNTY.

§ 1. Introduction, relation of physical geography and geology 31
§ 2. Level of Lake Huron 35
§ 3. Types of shore line 39
  (a) Mud flat, (b) sand beach, (c) cliff and shingle.
§ 4. Explanation of contour map 42
§ 5. Tables of altitudes 44
  (a) Lake survey bench marks 44
  (b 1) Port Austin Division 45
  (b 2) Harbor Beach Division, Pere Marquette R. R. 45
  (b 3) Pontiac, Oxford & Northern R. R. 46
  (c 1) Preliminary line of Saginaw, Tuscola & Huron R. R. 47
  (c 2) Goodman logging road 48
  (c 3) Main line Saginaw, Tuscola & Huron R. R. 48
  (c 4) Survey from Sebewaing to limestone quarries 49
  (c 5) Survey from Sebewaing to Kilmanagh, and Caseville 50

§ 5. Tables—*Continued:* Page.
(d) Miscellaneous data from W. L. Webber 50
(e) Cross-section near Port Austin 50
(f) Altitudes obtained by barometer 51
§ 6. The hill district 52
§ 7. The plain district 54
§ 8. The eastern shore 55
§ 9. The western shore 56

CHAPTER IV.

FORMATION OF THE SOILS AND SUBSOILS (PLEISTOCENE).

§ 1. The preglacial surface 59
§ 2. The ice age (Glacial epoch) 60
§ 3. The ice retreat (early Champlain, Terrace epoch) 62
§ 4. Lake retreat (later Terrace or recent epoch) 73
§ 5. Time estimates 78

CHAPTER V.

STRATIGRAPHY, DISTRIBUTION, AND STRUCTURE OF THE ROCKS.

§ 1. The Cuyahoga or Coldwater shales 86
§ 2. The Marshall sandstones 89
§ 3. Michigan series 98
§ 4. Bayport (Maxville) limestone 103
§ 5. Coal measures 113

CHAPTER VI.

WELLS AND BORINGS.

§ 1. Introduction, utility of the collection of records 118
§ 2. Practical lessons 119
(a) Quantity 119
(b) Head 121
(c) Quality 128
§ 3. Wells and well waters of the middle townships of Huron county, by C. A. Davis 131
§ 4. Mineral waters 134
§ 5. Chemical tests of well waters 138
§ 6. Systematic catalogue of wells and borings, by townships, from T. 15 to T. 19 N., Ranges 9 to 16 E. 142
Sebewaing 143, Brookfield 153, Grant 155, Sheridan 156, Bingham 157, Paris 158, Sherman 159, White Rock 159, Fairhaven 160 and 178, Winsor 163, Oliver 170, Colfax 173, Verona 174, Sigel 177, Sand Beach 177, Caseville 178 and 188, Chandler 182, Meade 185, Lincoln 187, Bloomfield 187, Rubicon 188, Lake 189, Hume 190, Dwight 192, Huron 196, Gore 198, Port Austin 199.

CHAPTER VII.

ECONOMIC GEOLOGY OR RAW MATERIALS OF THE COUNTY.

§ 1. Introduction 202
§ 2. Soils 202
§ 3. Sand 204
§ 4. Sandstones and grindstones 205
(a) Grindstone quarries 206
(b) The Babbitt sandstone quarry 207

Page.
§ 5. Shales and clays 208
White Rock 208
(a) Warren's brickyard, Badaxe 209
(b) Elkton brickyard 210
(c) Sebewaing 210
(d) Hayes 211
§ 6. Road metal 212
§ 7. Limestone 213
(a) Bayport limestone quarries 213
(b) Soule limestones 216
§ 8. Coal 217
§ 9. Ores, sulphides 220
(a) of iron 220
(b) of zinc 221
(c) of lead 221
§ 10. Salt 224
§ 11. Gypsum, or plaster of Paris 226
§ 12. Marl 226

CHAPTER VIII.

NOTES ON MINERALS.

§ 1. Introduction 228
§ 2. List of minerals 228

P. 228, Copper, galenite; p. 229, sphalerite, chalcopyrite, pyrite, marcasite, quartz; p. 230, chalcedony, chert, hematite, limonite; p. 231, wad, calcite, calcareous tufa, dolomite, sphaerosiderite; p. 232, feldspars, amphibole, garnet, epidote, mica, staurolite; p. 233, chlorite, kaolin, gypsum, melanterite, coal.

CHAPTER IX.

BOTANICAL NOTES BY C. A. DAVIS.

§ 1. Geological, geographical and practical relations of plants 234
§ 2. List of plants 238

CHAPTER X.

§ 1. Introduction 246
§ 2. Recent shells by B. Walker and A. C. Lane 247
§ 3. Fossils of the Marshall and Coldwater, by W. F. Cooper and A. C. Lane.. 252
§ 4. Fossils of the Soule and Bayport limestone 294
(a) Soule and Oak Point, Michigan series 294
(b) (Bayport) Maxville limestone 295

LIST OF ILLUSTRATIONS.

PLATES.

Page.
I. Geological column, showing the succession of rocks beneath Huron county, adapted to fit wells of Sebewaing, Bayport and Caseville...... title
II. View at Point aux Barques, looking southeast; showing the resemblance of the sandstone ledges to boats drawn up on shore, the undercutting action of the waves, and the Algonquin terrace 2
III. Illustration of the Point aux Barques sandstone; showing the undercutting of the waves on the weaker layers beneath, and the cross-bedding 24
IV. Illustrating the sand beach type of shore line. The beach near Point aux Barques, looking toward Burnt Cabin Point 40
V. Illustrating the fluctuation of level of the lakes, Michigan and Huron; from 1838-1858 from Crossman chart. Milwaukee gauge, 1856-1887 Lake Survey, previous to 1851 from early records of Geological Survey of Michigan, and paper by Chas. Whittlesey............................ 44
VI. The glacial geology of the thumb.—after F. B. Taylor........................ 64
VII. Map of the Paleozoic Geology of Huron county, showing the shape of the rock surface (by contour lines), and the distribution of the various formations; with a cross-section along the south line of the county.. 112
VIII. Map of the surface or Pleistocene Geology of Huron county, showing the topography by contour lines and the distribution of ancient shore lines and moraines and rock outcrops.. 208
IX. Illustrating glaciated surface of limestone. A freshly uncovered surface, with parallel glacial grooves........................ 216
X. Illustrating fossils of the Lower Marshall and Upper Coldwater, by W. F. Cooper .... end
XI. Illustrating fossils of the Lower Marshall and Upper Coldwater, by W. F. Cooper... end

FIGURES.

1. The Flagstaff (or Bowsprit) at Point aux Barques............................ 1
2. After Keyes, showing the oscillations of the shore line........................ 15
3. Illustrates the relation of sand and gravel ridges, boulder benches and flat sandstone exposures to ancient water levels.............................. 74
4. Illustrating the relative strength of the water lines at various levels in Huron county, Michigan.. 79
5. Ideal view of Point aux Barques lighthouse, showing the conglomerate and the fault 87
6. Sketch map of the eastern part of Huron county, showing by contours the shape and depth of the top of the Napoleon sandstone,—the best source of water.. 97
7. Illustration of section on Big Charity Island, showing discordance in the Bayport limestone. Completed so as to show the lower bands as we observed them, in dots. 105
8. Beds as given at Bayport quarries.. 110

Page.
9. Cross-section from Bayport quarries southwest, showing the relations of present surface, rock surface, flowing wells, and varying water level at point of intake 112
10. Sketch map of Saginaw coal region, showing location of some of the exploratory borings. The mines have not been mapped, but the dotted line indicates the danger line or area within which the workings are probably confined 114
11. Illustrating the relations of the coal and the fault at Sebewaing. This is a cross-section in a generally westerly direction, but the shafts and borings shown are not in line 115
12. Illustrates improper boring and casing, involving danger of contamination from surface waters, or of contamination of surface waters by a salty layer with strong head in A 124

TABLES.

I. Geographic names of Huron county, showing equivalents.........opposite 8
Precipitations and temperatures ....32 to 34
Elevations and profiles ....45 to 52
II. Physical properties of stones 90
III. Analysis of Huron county waters 135
Production of stone 207
Absorption tests on bricks 211
IV. Tests of Sebewaing coal 218
V. Statistics of coal production 220
VI. Statistics of the salt wells 224
List of plants 239
List of shells of the marls ....250 to 252
VII. Fossils of the (Maxville) Bayport limestone 298

ERRATA.

Page 2, line 24, dele inger.

Page 2, line 4, from bottom, for Grove read Gore.

Page 3, line 4, from top, for A. C. Poor read A. G. Peer.

Page 6, line 3, at end, read H. for F.

Page 12, line 31, for Grand Repids read Grand Rapids.

Page 13, line 1, for siliceous read silicious.

Page 17, line 7.

Page 21, line 9 and line 28, and on page 25, line 1, for Rhynconella read Rhynchonella.

Page 23, line 19, for Prœtus read Proetus.

Page 26, lines 13 and 17, and the foot note. Sand Beach is now Harbor Beach.

Page 27, lines 13 and 22, and on page 29, line 2, Sand Beach is now Harbor Beach.

Page 27, line 2 from bottom, for VII read VIII.

Page 28, line 17, for Hazard read Haskell.

Page 37, line 7, for N. W. read N. E.

Page 49, line above foot-note, for S. O. P. read S. Q. P.

Page 53, line 4 from bottom, for askers read eskers.

Page 50, line 3 from bottom, for 1886 read 1896.

Page 74, line 6 from bottom, for S. T. and H. R. K., read R. R.

Page 77, line 16 from bottom, for north, northwest, read north northeast.

Page 79, line 3 from below, for Gannet read Gannett.

Page 80, line 1, for Geo. W., read Geo. J.

Page 96, line 16, for Lounsberry read Lonsberry.

Page 100, line 19, for Sec. 7, read Sec. 6.

Page 106, line 4, for 19139, read 19189.

Page 117, line 14, read Lepidodendron.

Page 130, line 4 from bottom, for following read flowing.

Page 134, line 15 from below, for Raither read Rather.

Page 136, line 10, for Ayers' read Ayres.

Page 142, line 8 from bottom, for Miss. read Missouri.

Page 145, line 4 from bottom, for W. C. read W. T.

Page 171, last line, for Co_2 read CO_2.

Page 171, line 2 from bottom, for W. B. read A. B.

Page 178, last line, for Mozier read Mosher.

Page 183, line 5 from below, for Cody read Codey.

Page 183, line 16 from below, for Mozier read Mosher.

Page 211, line 2 from bottom, strike out the word New.

Page 246, line 7, for Douglas read Douglass.

Page 255, line 16, for 18263 read 19263.

Page 267, line 18, for Solon read Solen.

Page 268, line 16, at the beginning read *O. rushense*.

Page 298, Table VII is misnumbered VI.

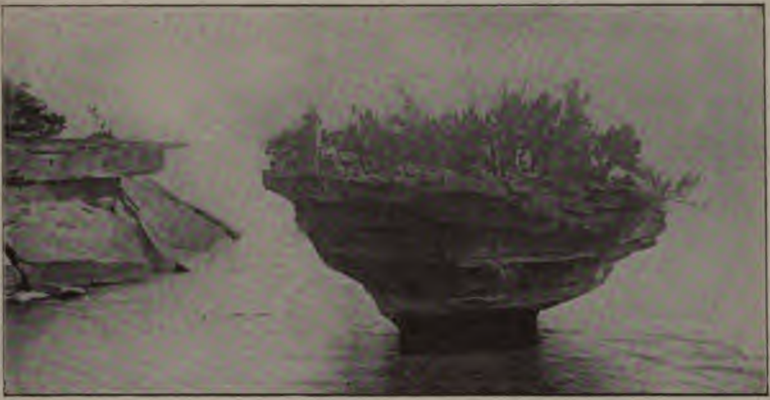

Fig. 1.—The Flagstaff (or Bowsprit) at Point aux Barques. The Thumbnail of Michigan, illustrating the undercutting action of the waves.

CHAPTER I.

INTRODUCTION.

§ 1. Historical.

The lower peninsula of Michigan has been likened to a man's hand. In such a comparison Saginaw Bay must be supposed to separate the thumb from the rest of the hand. Huron county is the end of the thumb thus formed, so that we may look upon the ledges which line its northernmost margin (Fig. 1), as representing the projecting thumbnail.

Few counties of the lower peninsula have more rock outcrops exposed than Huron county; and none, perhaps, have a greater variety of mineral industries. Coal, limestone, grindstones, and salt, are among the substances which have been already marketed, while pyrite, plaster, cement rock and mineral waters yet await development.

It is not surprising, therefore, that this region early attracted attention. Schoolcraft in his narrative* speaks of the coarse gray loosely compacted sandstone, after passing Elm Creek in the advance to Ship Point (Pointe Aux Barques). He continued up into "Saganaw" Bay to "Point Aux Chênes," i. e. Oak Point, and then crossed the bay, stopping at an island "which the Indians called Shawangunk," composed of a dark colored limestone, of dull and earthy fracture and compact structure. It presents broken and denuded edges at the water level." He observed in it nodular masses of chalcedony and calcspar. "The margin of the island bears fragments of the boulder stratum."

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*"Summary Narrative of an Exploratory Expedition to the source of the Mississippi River in 1820; with appendixes, comprising all the official reports and scientific papers of both expeditions. By Henry R. Schoolcraft. Philadelphia, 1855," pp. 54 and 310. There are two other editions.

This must be Charity Island, as he says it is about midway of the bay, and he says it is the largest of a group of islands, and southernmost in position. Usually there are but two islands placed upon the map, but when we were there in 1896 there was a small bar just out of water about half way between, and as we see from Plate V, at the time of Schoolcraft's expedition the lake was very low, and between that and 1856 some wearing away may have been done. We cannot understand how Schoolcraft called the largest island "southernmost." By a not unnatural mistake in an early explorer coasting along the shore he identified this limestone with that around Thunder Bay. For a long time investigation like settlement was superficial, and mainly along the shore of the county, and waited for the ax of the woodman to strip it of its covering of pine and lay it bare for exploration.

§ 2. Previous geological reports, Houghton, Winchell, Rominger. inger.

The very first annual report of the State Geologist[*] mentions the cliffs of Point aux Barques, whose picturesque beauty, reminding one of the prows and sterns of vessels, drawn up on the shore like the Greek fleet before Troy, suggested the name of the point to the fancy of the early voyageur (Pl. II).

Houghton's second annual report refers to the limestone of the Charity Island,[†] and the fourth annual report contains in Bela Hubbard's sub-report further details, and a correlation of the Point aux Barques sandstones with the Waverly sandstone of Ohio.[‡] In the state library are two old Mss. maps which I have used and think belong to Houghton's survey.[§] With the untimely death of Doug-

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[*] Douglass Houghton: Report of the State Geologist, 1838, H. R. No. 14, p. 9. Also H. D. No. 24, pp. 276-317 and S. D. No. 16.

[†] Second Annual Report of the State Geologist, 1839. H. D. No. 23, pp. 386-507, S. D. No. 12, pp. 264-391, H. R. No. 23 and S. R. No. 23 (misprinted No. 13).

[‡] 1841, p. 567 of H. S. and J. D. No. 11, pp. 472-607. This report was also issued separately as H. D. No. 27.

[§] For the magnetic variation on the coast at Sec. 17, Grove Township, is given at 1° 10′ 0″ E., whereas in 1858 the Lake Survey found it to be 8° 30′ E. at nearly the same point. Also a Mss. note refers to the state of a ledge in 1842, and there are many geological notes.

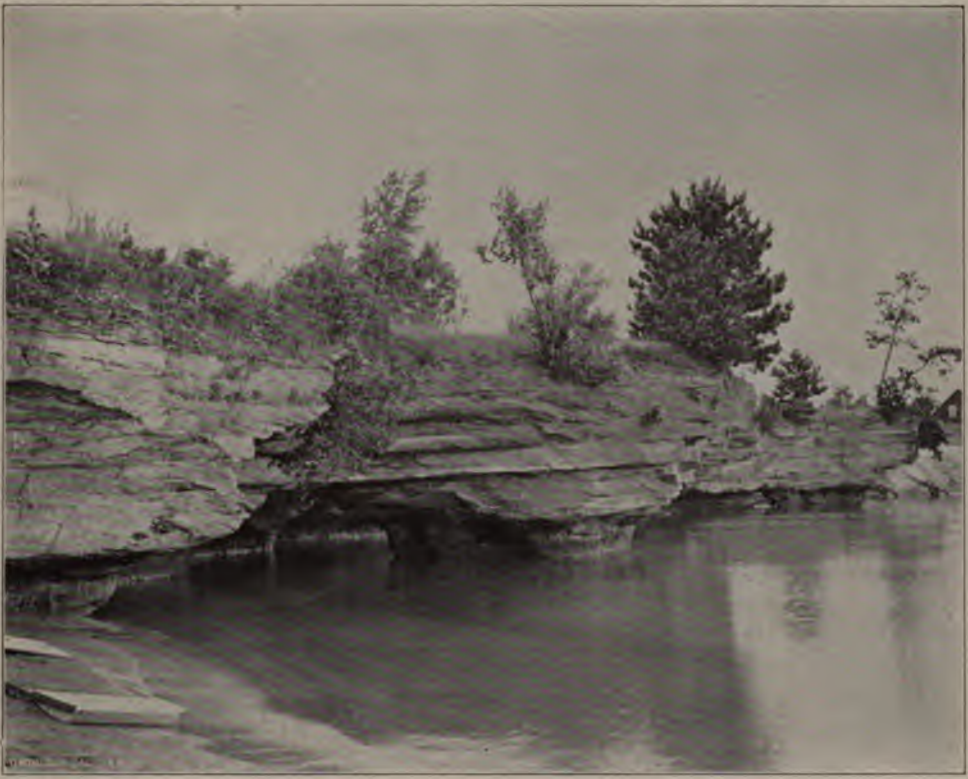

PLATE II.

Illustrates the resemblance of the cliffs at Point Aux Barques to the sterns of steamers, a small tree frequently playing the part of a flagstaff; the cliffs are composed of Lower Marshall sandstone and their upper level is determined by the Algonquin terrace.

(Reproduced through the courtesy of the F. & P. M. R. R.)

lass Houghton the Geological Survey stopped, and we have a period during which there is little recorded advance in local geological investigation. Yet during this time in 1850 the famous grindstone quarries were opened by Capt. A. C. Poor, and the product soon became widely known.

In the latter part of the fifties Alexander Winchell, Michigan's most eminent geologist, began his work and in his first report[*] we find a careful description of the rocks exposed along the shore. On page 75 he describes the rocks around the Point aux Barques lighthouse, and the grindstone quarries. On pages 80 to 82 he gives a description of the rocks of the Marshall group from Hardwood Point, on Sec. 35, T. 19 N., R. 12 E., past Flat Rock Point, "Point au Pain Sucre," to Point aux Barques. On page 88 he describes Pt. au Chapeau, on Sec. 7, T. 18 N., R. 12 E., as belonging to his Napoleon Group. The "Michigan Salt Group" he divined, without actually seeing it exposed, to be near the mouth of the Pigeon River, i. e., Caseville. This conclusion which we have verified, is a marked illustration of his sagacity as a geologist.

The Carboniferous limestone he recognized (p. 100) near the Shebeon, "Cheboyong" Creek, on the S. W. ¼ of Sec. 22, and the N. W. ¼ of Sec. 13, [Sic.] T. 16 N., R. 9 E., and on the shore of Wild Fowl Bay and its islands, viz.: on "Shungwoigue," otherwise called Stone Island, and on "Ashquaguindaigue," now known as North Island.

Finally he estimated that the coal formation should strike the lake near Sebewaing,—and the position of the Sebewaing coal mines, located as they are near the margin of the coal basin verifies his prediction (p. 121). Winchell was much interested in the rocks of Huron county, especially from a palæontological point of view, and he continued for many years publishing papers[†] in which fossils collected from Huron county were described or compared, which we can only refer to here, leaving their fuller discussion to the palæontological part of the report, Chapter X.

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[*] First Biennial Report of the Progress of the Geological Survey of Michigan. Dec. 31, 1860, Lansing, 8-vo., pp. 339.

[†] 1862. Descriptions of Fossils from the Marshall and Huron Groups of Michigan. Proc. Acad. Nat. Sci., Phila., XIV, 1862, pp. 405-430.

1862. Amer. Jour. Sci. and Arts, 2d Series, XXXIII, p. 353.

1863. Descriptions of Fossils from the Yellow Sandstones lying beneath the "Burlington Limestone" at Burlington, Iowa. Proc. Acad. Nat. Sci. Phila., XV, 1863, pp. 2-24.

On the Identification of the Cattskill Red Sandstone Group with the Chemung. Amer. Journ. Sci. & Arts, 2d Series, XXXV, 1863, pp. 61-62.

1865. Descriptions of New Species of Fossils, from the Marshall Group of Michigan, and its supposed equivalents in other states. Proc. Acad. Nat. Sci. Phila., XVII, 1865, pp. 109-133.

1865. Some Indications of a Northward Transportation of Drift Material in the Lower Peninsula of Michigan. Amer. Journ. Sci. & Arts, 2d Series, XL, pp. 331-338.

1869. The Mineral Fertilizers of Michigan, Report Department of Agriculture, Washington, Second Session, 44th Congress.

1871. On the Geological Age and Equivalents of the Marshall Group. Proc. Am. Philos. Soc., XI, 1871, pp. 57-82, 385-418.

1871. Notes and Descriptions of Fossils from the Marshall Group of the Western States, with Notes on Fossils from other Formations. Proc. Am. Philosophical Soc., XI, pp. 245-260.

Beside the papers mentioned in the foot note, which relate more particularly to the palæontology, other papers bearing more or less on the physical geography or geology of Michigan are as follows:

In 1871 he published an article in Harper's Monthly on the climate of the Great Lakes (XLIII, p. 279-281), to which we shall have to refer. In 1873 he prepared for Walling's Atlas (republished in 1883 by R. M. and S. J. Tackabury) a number of articles which were reprinted under the title "Michigan, Being Condensed, Popular Sketches of the Topography, Climate and Geology of the State" (8vo., pp. 121).

In 1875 he published a rectification of the geological map of Michigan, that he had prepared for Walling's Atlas,* and in 1878 prepared the chapter on Michigan in J. Macfarlane's "Geological Railway Guide," which gives the geological formation supposed to underlie each station. This book was revised in subsequent editions up to 1890. While, however, there is some progress indicated in these publications in the general conceptions of the geology of the state, there is nothing added to the detailed geology of Huron county which calls for especial mention.

In the meantime Dr. Carl Rominger had published in 1876 his principal work on the geology of the Lower Peninsula,—Volume III of the Reports of the Geological Survey of Michigan. That volume also contains a very valuable appendix by Dr. Garrigues, State Salt Inspector, on the various deep borings and their brines. In that report, which we do not summarize here as it is of the same series as this report, many outcrops not before noticed and many new deep borings, were described from Huron county, and a number of fossils, the two forms of Lithostrotion being figured. All these will be referred to in due place. Dr. Rominger added much to our detailed knowledge of Huron county and as we shall see took a somewhat different view of the stratigraphy around Port Austin from that taken by Winchell.†

The opening of the Sebewaing coal mines in 1890-1891 was announced in the reports of the Commissioners of Mineral Statistics, for 1890 and for 1891‡. On the map accompanying Rominger's report this area was indicated as outside the Coal Measures.

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*Proc. Am. Ass. Adv. Sci., XXIV, Part 2, pp. 27-43.

†Loc. cit., p. 76.

‡C. D. Lawton, 1890, p. 66; J. P. Edwards, 1891, p. 119.

§ 3. Recent work.

In 1892, when the present writer under the direction of the then State Geologist, M. E. Wadsworth, began editing the well records and other material which had been collected by Dr. Wadsworth's predecessor, C. E. Wright, his attention was naturally called to the discrepant views of earlier geologists, and, especially by Hon W. L. Webber of Saginaw, to the advances that had since been made in the development of the county. Beside the coal mining and grindstone quarrying there had been considerable quarrying around in the neighborhood of Wild Fowl Bay, the large Bayport quarries being opened in 1888. Thus, though the report of Volume V gave the data then at hand, the county was recognized as one where farther field work promised economic and scientific rewards. The writer made a preliminary visit in December, 1895, and in 1896 the summer was spent in field work there. During part of the time he was assisted by Dr. C. H. Gordon, and by Prof. C. A. Davis of Alma College. Prof. Davis and the writer have worked Ranges 12, 13 and 14 together, and the botanical notes are entirely, and the plan of the chemical work largely, due to Prof. Davis. The western Ranges 9, 10 and 11, have been more particularly studied by the writer who is also generally responsible for the assembling of the data, the language of the report, and the construction or preparation of the illustrations.

During the same summer Messrs. F. B. Taylor and G. K. Gilbert of the U. S. Geological Survey made a rapid visit to the county, being engaged in tracing the old lake shores. The result of Mr. Taylor's work was given to the public that summer at the meeting of the Geological Society of America, and published in an important paper to which we shall have frequent occasion to refer.* A map from this paper we have with his permission reproduced in Plate VI, as it gives a good idea of the general relations of Huron county geographically as well as its position and relations during the Champlain epoch and in general we are guided by Taylor in naming and correlating the beaches.

The county has also occasionally been visited by other geologists, whose notes so far as we are informed have not been given to the public.

This report was chiefly written in the winter of 1896-97. In the fall of 1897, incited thereto by the writer, who sent a short unpublished abstract of his results to the meeting of the A. A. A. S. in Detroit, that fall, the county was visited by W. F. Cooper, who has done much work on similar beds in Ohio, and by Mr. George F. Girty of the United States Geological Survey. The writer guiding Mr. Girty also revisited the county, especially studying the eastern part around Harbor Beach which he had not previously visited, and doing some additional work on Ranges 14 and 15, and studying the rate of erosion on the eastern shore. Mr. Girty and Mr. Cooper have added to our palæontological knowledge of the county, and material by Prof. A. Winchell and by Mr. Cooper add much to the value of the palæontological chapter.

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*Bull. G. S. A., 1897, Vol. VIII, pp. 31-53.

At the same meeting Mr. Gilbert read a paper on the change of level of the land around the Great Lakes,* which incorporates some observations which he made or had made in the county. Other work has prevented anything but a cursory revision, prior to publication, in the fall of 1899. Some work for the survey on the clays and shales by H. Ries and on coal by H. J. Williams has been included.

§ 4. Acknowledgments.

While Messrs. Gordon, Davis, Cooper and the writer have been directly employed by the Survey, the value of this report is largely due to the records carefully kept and freely furnished them by others, whose disinterested love for science and appreciation of the importance of scientific facts deserve a word of mention here. Too often are records and samples which are of great scientific value, and may later be of money value, thrown away because of no immediate importance.

Among those who have thus furnished valuable material to the Survey, Hon. W. L. Webber of Saginaw may first be mentioned, for the whole determination of altitudes rests primarily on lines of levels freely furnished by him, without which the work would everywhere be distinctly less accurate. Not only this, but he has also given access to records of various explorations, and rendered the work of the Survey every assistance in his power.

The officials of the Pere Marquette Railroad Company have also been most courteous, both in response to inquiries, in loaning illustrations and in other ways. Much information has also been derived from well drillers, who have always shown a willingness to help the Survey in its work. For example Mr. John Russell of

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*Nat. Geog. Magazine, Sept. 1897, VIII, pp. 233-247; also 18th Annual Report U. S. Geol. Survey, 1898, Part II, p. 624.

Unionville, to whom is largely due the credit for the development of the Sebewaing coal mines, gave access to the records of borings for water which he has been carefully keeping for years, and he and Messrs. Hofmeister, Bullock, Smith and others have saved samples of the wells they were engaged upon. Want of space forbids a detailed enumeration of all those residents of the county who have assisted us. Their names will, to a large extent, be found scattered through the report as authority for the various data. In return for their courtesy it is hoped that this report may do something toward advancing the interests of the county, assisting in more intelligent and economical development of its water supply, in more extended use of its other varied natural resources and in more interesting teaching of physical geography and natural history by illustrations drawn from natural features near at hand. Outside the district the Survey is under obligations to Bryant Walker, Esq., of Detroit, who has determined the shells of the shell marl, with the exception of the Pisidia; to Dr. Victor Sterki, who determined the latter, to the U. S. Geological Survey for numerous favors, and to the U. S. War Department for loan of original field sheets to be photographed.

§ 5. Maps.

The maps in the State Library referred to are interesting as recording forgotten names and islands which have vanished.

The only geological maps of Huron county are those incorporated in some general map like those issued by Winchell in Walling's Atlas (loc. cit.) and by Rominger and Lane, in Volume III, respectively V, of this series of reports. As to the topographical maps, the early maps prior to the U. S. Land Survey in 1845 and 1848, are sufficiently well represented by Jeremiah Greenleaf's Universal Atlas of 1848. They are far from accurate. White Rock is half way down in Sanilac county. Willow Creek, called Black River, empties into a marked bay between Rogers Point and Pt. aux Barques, which is about where Burnt Cabin Point should be. Sugar Point is perhaps Flatrock Point, and the Pigeon River masquerades as Sugar River. Oak Point is Pt au Chenes. Charity Island is Shawangunk, and the islands off Wild Fowl Bay are rolled up into one mythical I. au Traverse and planted square across Saginaw Bay.

1856. Farmer's map in 6 sheets, 7½ miles to the inch, summarizes the result of the United Land Survey, and was a most excellent map. This was issued and reissued, in various scales and at various dates.

1871. Walling's County Atlas of Michigan, already mentioned, contains beside the geological map of the state, a separate map of Huron county, which is interesting historically, in showing streams lakes and roads now no more, and occasionally it is more accurate than recent maps. We used blue prints of this to some extent. It was derived from the notes of the United States Land Office, and shows the original courses of the streams which have in some cases been much changed by ditches. The Land Office maps also show the original swamp areas.

1872. I have a sectional map of this date with no author nor publisher given which seems to follow Mss. maps in the State Library at the Capitol, that are independent of the U. S. Land Office, already referred to.

1875. In this year a large county map on the scale of two inches to one mile was issued by F. W. Beers of Philadelphia. This map showed ownerships.

1883. The Walling atlas was reissued with added railroads by Tackabury.

1890. An Atlas of Huron county was published by E. R. Cookingham and Company, with a general map of the county on a scale of one-half inch to one mile, with township maps on a scale of two inches to one mile, and village plats mainly on a scale of four hundred feet to one inch. These were largely constructed from deeds in the County Records, and have been the principal base of our map. Some use has also been made by us of the profiles of drains filed in the office of the County Drain Commissioner.

In 1856-7. The United States Lake Survey carefully surveyed the coast of Lake Huron in this region, and the Chart of Saginaw Bay, published in 1860, gives the results on a scale of 1: 120,000, very nearly one-half inch to the mile. As above mentioned we have been permitted to use photographs of the field sheets, which were on a scale of 1: 16,000.

The following list of names which have been applied to the geographical features may be of service. There are three types of names,—those of English, of French, and of Indian derivation. In many cases one is a translation of the other.

TABLE I.—GEOGRAPHIC NAMES OF HURON COU
NAMES ARE ITALICIZED. THE ORDER IS GEOG
THE S. W. CORNER.

English.	Authority.
White Rock	C., L.O.,T,Ro., R.
White River	C., T.H.
Elm Creek	C., T., L.S
Purdy Bay, Sec. 5, White Rock Tp.	L.S
Sharpe Bay, Sec. 35, T. 16 N., R. 16 E.	L.S
Allen Creek	T., L.S.
Rock Falls	C., L.O.
Spring Creek	T.
Center Harbor	L.S
Crane Point	
Drowned Point	
Forest Bay	L S
Hardwood Point Creek, emptying on Sec. 15, Rubicon Tp	L.S
Whiskey Harbor	S.
Diamond Creek	T.
Section 29 Gore Tp.	M.H.
Poplar Pt.	
Rogers Pt., Sec. 12 Huron Tp	H.W., R.R.
Willow River	T.S
Black River	M., H.
New River	T., R., L.S., M.
Pine River and Bay	H
Burnt Cabin Pt	L.O., Wi., Ro., K.
Eagle Bay	
Ship Point	S.
Grant Creek	C.
Birds Creek	C.
Flat Rock Point	L.O., T., Wi., Ro.
Hard Wood Point	Wi., L.S.
Partridge River	L.S
Pigeon River	H
Hat Point	L.O., Ro., L.S.
Or Loosemore Point	Local
Rush Lake	C., L.O., T., L.
Little Oak Point	L.S
Oak Point	L.O., T., L.S., H.
Pigeon River	L.O., Wi., R.R.,
Charity Island	T.L.S.
Great Charity Island	Wi.
North Charity Island	
Little Charity Island	Wi.
South Charity Island	
Sand Point	L.O., T., R.R., L.
Fishing Point	
Mud Creek	
Wild Fowl Bay	L.O., T., Wi., R
North Island	C., L.O., T., L.S.
Stone	Wi.
Stony	L.O., L.S.
Spooney	R.R.
Heisterman	C.
Heinzelman?	Ro
Warner	R.R.
N. Pond Island	R.R., M.
S. Pond I.	R.R., F.
Pond I.	H.

Abbrevations:
Schoolcraft's Narrative, S.
U. S. Land Office, L. O.
U. S. Lake Survey, L. S.
Walling Atlas, and Tackabury's reissue, 1883, T.
Cookingham's Atlas, C.

UNIV OF MICH

CHAPTER II.

GEOLOGICAL COLUMN.

§ 1. Pleistocene, i. e., unconsolidated materials, soils, and subsoils. (a)*

Although repetition is involved, it is best to give at once a general account of the principal materials which make up the frame of the county, geologically speaking, whether rocks in the popular sense, or soils, or subsoils. At the same time we may give some reference to their nearest representatives elsewhere, for so one will be able to understand more intelligently references to them scattered through the text. A more detailed account of their character may be gathered from the chapter devoted to their distribution.

An imaginary section down into the earth's crust, showing the various materials of which it is composed at any place, is called the geological column at any place. Plate LXXIII of Vol. V, of these reports, gives such a geological column for the Lower Peninsula. We proceed therefore, to give an account of the geological column under Huron county (Pl. I).

Our first division includes the materials most recently laid down, or even now in process of formation. Such are the finer material, called sand, and the coarser material,—called shingle and gravel,—of the present shore lines. Along the west coast the sand is frequently blown back from the beach into undulating mounds known as dunes. Off shore and in shallow waters muds and oozes are forming. The streams deposit "alluvium," that is silt and sands and even gravels, especially along their courses upon their flood plains in times of freshet. In the smaller lakes and in the great lake in sheltered stretches we find shell marls forming, mixtures of mud, decayed vegetation and the cast off shells of fresh water snails and similar animals with precipitated lime. Such shell marls make, if drained, a wonderfully fertile soil and are also coming into demand for the making of cement. Such a lake, once known as Bear Lake, has been drained just southwest of Port Austin and the land is said to yield unusually large crops of timothy. Out from the edges of the lakes, as is well seen around Rush Lake, the marsh creeps slowly but surely, fills them up, and makes deposits of muck or peat, converting them into swamp. Occasionally masses, or irregular sheets, of bog iron ore are formed, the iron ore being leached by organic acids out of the surrounding sands, which are left unusually white, the iron being later reoxidized and deposited.* Waters thus charged with dissolved iron become covered with an iridescent scum on becoming exposed to the air. Such scums are well marked on the shore west of Caseville, and are sometimes mistaken for oil, by those who do not observe closely, but they lack the characteristic odor, and the sheet of scum breaks up into angular forms. A similar type of chemical deposit is that formed by the deposition of lime from calcareous springs when they reach the surface. Such deposits of calcareous tufa or travertine, as they are called when they form exposed to the air, were observed around a spring in the bank of Willow Creek, while if they form beneath lakes or bogs they produce marl or bog lime. Similar materials to those now forming in these different ways we also find where they cannot have been formed under present conditions. Thus rolling ridges of dune sand swing southwest from Caseville to Bayport, cutting off Sand Point, far from the present shore line. Thus, too, south of Badaxe beds of shell marl exist under the muck, where there is no longer any pond, and even the marsh is fast being drained. Again near Huron City cliffs overlook benches of shingle, where no storm could now sweep the waves of Lake Huron. Around Pigeon, Elkton, and Badaxe, and often elsewhere we find beds of clay evidently deposited in a body of water. In fact all over the county ridges of sand and gravel are found, and long trains of boulders, which are like the present shore line formations.

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*This letter and corresponding letters in parentheses below, have the same meaning as in Plate LXXIII of Vol. V.

These we still class as recent deposits, but we see that we must look far enough back into history for the time of their origin, to find a somewhat different physical geography from the present. In the county we also find deposits, still unconsolidated, and not rock in the popular sense, but often firmer and more solid than those already mentioned and classed as "hardpan," whose origin we can ascribe to no agent now working in the county. The deeper cuts in the hills around Verona or Ubly show well these deposits. All water deposits show some banding and stratification and in them the material is assorted according to grain, and especially is the very fine clayey material (0.005 mm. in diameter or less) washed out from the coarser and deposited separately. The coarser stones are also more or less rolled and rounded. But in the material we are considering, whose shortest name is "till,"* we find stones of various sizes and irregular, frequently of angular or grotesque shape, firmly compacted together with a clayey cement. The stones and boulders which we find in this deposit, and also strewn over the surface of the county, are not derived altogether from rocks which are to be found in ledges in the county, but come from far away in Canada,—a conspicuous jasper conglomerate with blood red bits of jasper sprinkled here and there in the white quartz, masses of vein-quartz, heavily loaded with pyrite, granite, hornblende and staurolite schist, etc. This material is such as is deposited under glaciers, and the glacially grooved surfaces of the limestone in the Bayport quarries (Pl. IX) also give evidences of the presence of a vast sheet of ice that once came down from Canada, and crept heavily over the country down to the Ohio River. The period of this ice sheet is known geologically as the Pleistocene, or Quaternary. Contemporaneous with the presence of the ice sheet, deposits like those now forming were laid down in front of its margin, as it retired.†

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*Prof. Davis observed a good instance of this leaching of iron oxide on the southeast ¼ of Sec. 36, T. 15 N., R. 10 E., Sp. 19174.

§ 2. Coal measures of Sebewaing. (b)

The formation known as the Woodville sandstone, a reddish sandstone, separated off by Winchell, but not by Rominger, is not represented. It may perhaps once have existed, for we find the unconsolidated deposits resting on an uneven surface with stream valleys cut into it, which now are entirely filled and hidden. Such a surface indicates what is known as an unconformity between the deposits above and those below. From what has been learned elsewhere we know that this unconformity is a sign that for many more years before the ice period, than have slipped away since that time, this rock surface was a land surface which stood above sea level and was carved and eroded away by running streams. Possibly during that time the Woodville sandstone and others of the uppermost rocks were entirely wasted away.

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*The term "boulder clay" is not a very happy one for Huron county for the ground moraine often has not many large stones, and is typically rather a gravelly clay.

†Taylor, loc. cit.

Passing now to what we have left of the Coal Measures, the well records of Sections 7, 8, 17, 18, of Sebewaing township, from about 50 to about 125 feet down, show the character of the rock. Rominger's remark* is quite applicable; "the whole series is a constant alternation of shale and sandstone beds, and every natural or artificial section teaches us that an immense variety exists in this alternation." It will be observed that red colors do not prevail, but white and bluish to black. The shale is in streaks black and bituminous. At two horizons, at least, occur seams of coal, one of which tends to be about 4 feet thick, but may be somewhat thicker, and often is cut out entirely. Sandstones run from white to gray in color. The whole formation is more or less charged with pyrite. Carbonates of iron, magnesia or lime occur in nodules or thin bands and zinc blende (ZnS) may occur in similar form. The clay beds under the coal are often called fire-clay, but the clays like the other beds vary rapidly in short distances. For example the heavy clay in Bauer's well and that in Miller's well, both in Sebewaing were quite different, the one being much "fatter" than the other. Black bits of fossil rushes are not uncommon in them. There are from 50 to 75 feet of clay above the principal coal deposit and less than twenty below it. I assign to this group, say, in all—75 feet.

At the bottom of the Coal Measures a sandstone is separated off by Winchell under the name of Parma sandstone.† But the dip of 45°, which he gives, shows that there is something abnormal about it, and Rominger fails to recognize it as a separate horizon.‡ Only a trace of it is found in Huron county, e. g., in Bauer's well, Sebewaing, from 101-104 feet, though it seems about Bay City and Saginaw to be well marked, but even there it belongs, I conceive, rather with the next group lower.

§ 3. Maxville limestone of Bayport.

The Grand Repids Series (c), in Huron county, can be easily divided into two parts: the upper being the limestone of Bayport, equivalent to the Maxville limestone of Ohio.

This formation is composed of limestone, alternating with, and at times frequently replaced by beds of white sandstone, thus resembling the Kaskaskia of Indiana.§ The sandstone is often calcareous and very fossiliferous, and the limestone is inclined to be very cherty with rounded siliceous concretions. The lower beds are often brown and dolomitic. The first fifty feet of the Bayport limestone quarry section,—on Sec. 5, T. 16 N., R. 10 E. (Fig. 8), is the most detailed division of the formation that we have. It dwindles to some 20 feet around Sebewaing (Sec. 8, T. 15 N., R. 9 E.). As above said, I believe that this formation in its sandy phase is the Parma sandstone, and we have not been able to follow in detail the subdivisions made by Winchell. It is a good source of water. It is the equivalent of the Maxville limestone of Ohio, which has been identified with the St. Louis-Chester (or, as it is now called, the Kaskaskia), as is evident from comparison of the fossils with those of Plates IX and X of Whitfield's paper on the Ohio Subcarboniferous.* For geographic reasons explained a page or two beyond I correlate it with the upper St. Louis, as long ago suggested by Winchell from the palæontology. It is also equivalent to the limestone at Grand Rapids, as is evident from a comparison of their fossils. The most abundant genera are Allorisma, Lithostrotion† and Productus. Good natural exposures are found, as stated by Winchell and Rominger.

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*Loc. cit. p. 128.

†Loc. cit., 1860, pp. 112, 138.

‡Loc. cit., p. 128.

§20th Annual Report, State Geol. of Indiana, 1895, pp. 330-331.

It is liable to be eroded by underground water channels, which cause sudden drops in the drilling, as at Sebewaing, Sec. 8, T. 15 N., R. 9 E. For a round number, near the maximum we may call its thickness 50 feet.

§ 4. Michigan series (c, 2).‡

This group of rocks is in general soft and forms valleys in the rock surface, as we see from the map (Pl. VIII), and is therefore little exposed. Just off Oak Point and near Soule the lower part of the formation lying on the more resistant sandstone beneath is brought within reach of erosion, and thus exposed to daylight. Light grey and greenish shales, very fine grained, somewhat sandy or micaceous and pyritiferous, predominate but at various levels as around Soule, at about 70 feet above the coarse underlying Napoleon sandstone, occur beds of impure clayey bluish magnesian limestone, weathering buff, which closely resemble those used at Milwaukee for cement.

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*Geology of Ohio, Vol. VII.

†The Lithostrotion and Zaphrentis have already been figured by Rominger, Vol. III, Plate LV; other forms will be illustrated in reports on Kent county and Arenac county.

‡I would suggest that from Winchell's name the word salt be dropped. While the group is a source of brines, perhaps, rock salt has hitherto been found in it only as a mineralogical curiosity, the really characteristic mineral being gypsum. Moreover, as there is no other group of strata called simply Michigan the term salt is unnecessary. Finally this group in its characteristic gypsiferous facies occurs extensively in Michigan, and, so far as we know, not outside the State, so that the name Michigan series will be very appropriate. If a local name were desirable the town of Alabaster has best claims to the honor of naming it.

Toward the bottom of the series (cf. Dufty's and Sovereign's wells in Lake township) the shales are darker and more bituminous. In the shales also occur lenticular beds of gypsum, which is white when pure, but when impure bluish and hardly to be distinguished from shale. About 80 to 120 feet from the bottom of the formation and not far above the cement rock of Soule is the most marked gypsum horizon (see also well on Sec. 36, T. 17 N., R. 11 E.) and at this level and a little higher the water is very bad. There are signs of another gypsum bed about 20 to 30 feet below the top of the shale. In general the water from this formation is scanty, characteristically highly charged with sulphates, and often cathartic, or almost too salt for use. Unfortunately we have no good characteristic set of samples from the thicker part. Bauer's well, Sec. 8, Sebewaing, from 127 to 249 feet and Deeg's well on Sec. 35, Sebewaing, from 66 to 130 feet, are the most complete records we have, but are from its thinner part. Collison's well (Sec. 14, T. 16 N., R. 9 E.) probably gives only the lower part, while it is probable that under Bayport and to the north this Michigan series is two hundred feet thick and perhaps a little more, with argillaceous dolomitic limestone at the bottom and about one-third the way up, and gypsum beds halfway up and also less marked near the top, being thus quite as thick as at Grand Rapids.*

The base of the Michigan series near Soule appears from the wells to be of micaceous shales like those in the Marshall, while near Oak Point, Rominger describes beds like the Soule cement rock directly above the sandstone. Winchell† seems to include some part of these micaceous shaly beds in the Napoleon.

The general correlation of this group we can fix very nicely from geographical considerations. The gypsum beds must have been laid down in a nearly enclosed sea. Hence the adjacent country must have been out of water, and our correlation for these beds must be with some series that is wanting in adjacent regions. Now in just the proper part of the geological column in Ohio there is a group which is wanting in northern Ohio and southern Michigan. "By atrophy or overlap" the Logan Group "is wanting in the Cuy-

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*Vol. V, Pl. XXI.

†Am. J. S. XXXIII, 1862, p. 353.

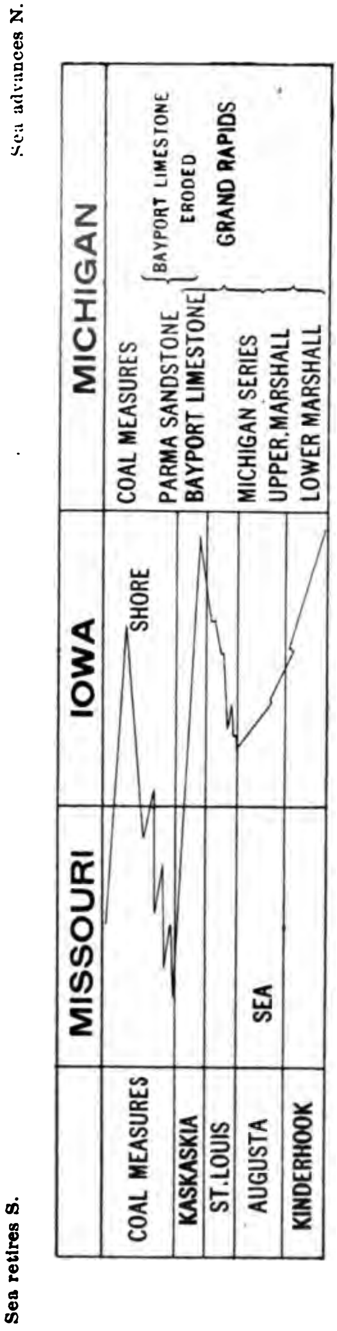

Fig. 2.—After Keyes (Geol. Survey of Iowa, Vol. II, p. 114), showing how the shore line advances to south and returned north during and before the deposition of the coal measures, and connecting the Missouri, Iowa and Michigan beds. The irregular line is as given by Keyes. For the relations of the shore line in Michigan, see text.

ahoga Valley, or is at least very inadequately represented there."* Again if we turn to Indiana we find† that the Burlington has not been satisfactorily identified in that state. In each case the missing part of the column lies close below the St. Louis and Maxville limestones, respectively, which we have identified with the Bayport limestone, and so to anticipate a little we suppose that the general continental emergence which culminated in the heavy sandstones of the Catskill in New York and the Napoleon in Michigan (the former being formed before the latter, as the shore line advanced west and the emergence progressed) finally lifted Ohio and Indiana largely out of water, while part of Michigan remained as a closed basin between these lowlands to the south and the great mass of land to the northeast and (for the indications are that Wisconsin was also out of water) northwest. In the sea thus enclosed the "Michigan Salt Group" was formed, while the Logan Group formed on the other side of the low land which extended through northern Ohio and southern Michigan.

Even as far away as Iowa‡ there are corresponding facts. (Fig. 2.) "In some portions of the Mississippi basin there were very considerable alterations in the coastal

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*Geol. Ohio, VII, p. 32; cf. also pp. 510 and 515.
†Geol. and N. H. Survey, 15th Ann. Report State Geologist, 1885-6, p. 12.
‡Iowa Geol. Sur., I, 1892, p. 66.

contour of this broad shallow gulf during the latter part of the Lower Carboniferous, and it is known that there were even greater changes in the coast line in the other parts of this region during the same period. During the Keokuk the waters over portions of Iowa, Illinois, Missouri and Indiana, became greatly diminished in depth, and the land of the same area was considerably extended. While the St. Louis beds were being deposited the sea again encroached upon the land, extending in some places more than 200 miles northward, beyond the former Keokuk waters."

This is illustrated by Fig. 2 and is in complete accord with what we find in Michigan, only we must remember that the effects of an elevation of the Canadian continent would be felt sooner near by in Michigan than in Iowa farther from the old Laurentian land mass, and the effects of depression later. Thus the Bayport limestone will represent the farthest extension of the St. Louis depression,—the top of the St. Louis,—while the beginning of the Michigan (Salt) Series will be earlier than the Keokuk. In other words the Michigan series is closely equivalent to the Augusta, i. e., Burlington and Keokuk formations which are stratigraphically very closely allied.* The palæontological evidence sustains this conclusion. (See Chapter X, § 4.) Its thickness is not out of harmony with our conclusions, for to match with 230 feet of the Augusta in Iowa and 150 feet of the Logan in Ohio, we may estimate the thickness of the Michigan group from the Bayport well, at 232 feet.

§ 5. Marshall series. (d)

Beneath the cement rock series comes an extensive sandstone series which forms the points which project from the north shore of the county from the Babbitt sandstone quarries (Lot 3, Sec. 15, T. 18 N., R. 11 E.), to the grindstone quarries. Of these points Hat Point, Flat Rock Point, and Point aux Barques, are supposed by Rominger to represent the same horizon (loc. cit., p. 75), while Winchell supposes a general descent in the series as we go east. The reasons why I consider Winchell's conception of the column to be more nearly correct are as follows:

The coast of Huron county was lined with saltworks, supplied by deep wells which appear to have drawn their brine largely from the same source, namely the Berea grit. If we compare the depths of these wells we find them steadily deepening to the west through the disputed area, as described below under Chapter V, in a way which does not seem to indicate the anticlinal and synclinal supposed by Rominger. Moreover we can trace the individual beds of sandstone in the shallow wells for water until they run under one another, and by thus showing that they cannot be identical, confirm the presumption raised by the salt wells. For example, the heavy sandstones of Flat Rock Point and Port Austin can be traced in wells and by outcrop (Sec. 3, Dwight, T. 18 N., R. 13 E.) to Sec. 13, Dwight, where Robinson's well starting at their outcrop, runs down 101 feet to draw its water supply from the Point aux Barques sandstone, which can be similarly traced through sections 22, 23, 26 and 35, Port Austin, T. 18 N., R. 13 E., and Sec. 1, Dwight, T. 18 N., R. 13 E., to its outcrop on Willow River (S. 28, Huron township).

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*Geol. Sur. Iowa, 1892, I, p. 59.

It is true, indeed, that about Hardwood Point abnormal dips to the northeast and possibly a fault are indicated, and a much greater maximum thickness for the Marshall series must be allowed than was assumed even by Winchell.[*] Thus we are somewhat puzzled where to put the base of the Marshall, so as to agree best with his idea, who is the geological sponsor for the word. He speaks, indeed, of the fossils of Hardwood Point (Sec. 35, Port Austin) as the first undoubted Marshall fossils,[†] and in the same report describes the "gritstones" and grindstone quarries (p. 75) in connection with the underlying shales of the Huron group. On page 80 he alludes to the conglomerate 235 feet below the top of the Lower Marshall as containing some of the fossils of the overlying group, and in the table on page 139 he makes this conglomerate the base of the Marshall and separates the Napoleon from the Marshall, placing the former in the Carboniferous, the latter in the Devonian; later, however, he speaks of the Marshall as "outcropping in the sandstone bluffs of Point aux Barques,[‡] and on his map and in his fossil lists and publications he includes in the Marshall the fossils of the grindstone quarries of the Huron gritstones. If we put the base of the Marshall at the base of the Point aux Barques sandstone it would be the best place to have it, in order to make his statement hold true that in the Marshall brachiopods, except Rhynconella are rare. For immediately below comes the zone of [*Camarotœchia R.*] *camerifera* and *Romingerina* [*Centronella*] *julia*, crowded with brachiopods and with a different faunal aspect from the beds above. However, inasmuch as Winchell distinctly includes these and the fauna of the gritstones,[*] among his Marshall forms, we are constrained to bring the base down so as to include the quarry beds around Grindstone City, with the associated conglomerates.[†]

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[*] Am. Jour. Sci., 2d Series, Vol. XXXIII, 1862, p. 353, 296 feet; in a later publication 283 feet.

[†] Report, 1860, p. 80.

[‡] Walling's Atlas, 1873, p. 41.

These gritstone beds moreover, seem in their outcrop on Willow River to be coarser and more massive, and more like the Point aux Barques sandstones and in fossils and lithology close allies of the beds above.

Rominger says that Winchell put the base of the Marshall still farther down, just above the conglomerate that underlies the lighthouse (loc. cit., p. 75). This does not appear to have been Winchell's view for we have not only his maps and the numerous references already given, but he distinctly says (Proc. Acad. Nat. Sci., Phila., 1862, p. 406) that the bed in question is intercalated in argillaceous shales of the Huron group and excludes the fossils thereof from the lists of Marshall forms. The other point of Rominger's criticism, that at least 500 feet of rock beds below this horizon present the faunal characteristics of the Cuyahoga shale of Ohio, which forms the upper division of the Waverly group (Subcarboniferous) is well taken, though we must remember that Herrick would divide these shales and assign the lower part of them to the Devonian. There is a practical advantage in drawing the line where we do, in that it may be more easily traced in the well records, and is at the same time of more practical importance. For wells into the Marshall as thus defined are pretty sure to strike good water. Limiting the Marshall thus, it is at maximum 560 feet thick, and we may subdivide it, following Winchell's earlier work into Napoleon or Upper Marshall and Lower Marshall.

§ 6. Napoleon or Upper Marshall sandstone (d 1).

We revive this term from Winchell's report, as being applicable to this county.[‡] The Napoleon is typically a white sandstone though often with a faint olive or greenish cast. In well samples it is frequently quite pyritiferous, and to the pyrite is doubtless due small brown mottlings, which appear in it where exposed in outcrop. Hat Point (Sec. 7, T. 18 N., R. 12 E.) seems to be near the base of the formation; if so, there must be nearly 300 feet of sandstone without important interruption. This is indicated both by such wells as Mr. Dufty's on section 32, and Lonsberry's on section 35 of Lake (T. 18 N., R. 11 E.), and by the considerable breadth of its outcrop. To the southeast under cover its recognizable depth rapidly diminishes to somewhat over 100 feet, as at Bayport (135 feet), Pigeon (110 feet), etc. It yields an ample supply of fresh water when properly cased. The thickness of 300 feet above mentioned is not obtained directly, and may include, as did Winchell, some of the bluish micaceous sandy shales which we have estimated in the overlying group. Thus it is probably near a maximum, but implies a dip from Hat Point to Caseville closely in accord with that indicated in other ways, as shown in Chapter V, § 1.

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[*] i. e. the quarry beds below which were in his time on Sec. 30, T. 19 N., R. 14 E.; cf. Proc. Acad. Nat. Sci. Phila., 1862, p. 305; Am. Phil. Soc. (1870), Vol. XII, p. 386; Report 1860, p. 74.

[†] As he does in Am. Jour. Sci., 1862, 2d Series, Vol. XXXIII, as well as in the latter publications.

[‡] Winchell seems to have abandoned it in 1875. The reason probably was that not finding in the deeper wells of the Saginaw valley any well-pronounced sandstone beneath the 109 feet from 633-742 feet, he concluded as suggested on p. 90 of his 1860 report that this one sandstone represented both his Napoleon and Marshall. Whereas the indications are, as will be shown in the chapter on Stratigraphy, that the lower fossiliferous Marshall of Huron county is there represented by the red shales beneath the sandstone and some of the underlying beds, shown in the record of the Bay City well in Vol. V, Pl. VI, of these reports. Winchell's first thoughts were best.

§ 7. Lower Marshall series. (d 2.)

This group is in rocks and fossils a transition one, and varies from point to point. Lithologically it is a transition from the heavy sandstone overlying to the heavy shale formation underlying. There are three prominent types of rock:

(a) A conglomerate with small very round pebbles of white quartz, and a copious clayey cement—the same material as types b and c—which when fresh may be bluish or greenish, but is reddish when weathered. The rock then resembles peanut candy. We may call it peanut conglomerate.

(b) A fine grained bluish sandstone or grit, impregnated with more or less carbonates, especially of iron, and thus passing into clay iron stone, which often cements the sandstone into rounded balls or nodules. When weathered they become very rusty, brown or red.

(c) Bluish micaceous shale which may be very clayey (a wide spread lithological type in the middle Kinderhook; cf. Missouri Geol. Sur., Vol. IV, p. 51). Gradations and interlaminations of these types compose the whole formation which has a characteristic bluish to greenish gray color when fresh and a red color when oxidized, and is throughout quite micaceous and ferruginous. These three facies remind one of the Catskill, Chemung and Portage types of

New York State. The uppermost beds of the group we find on the hill back of Port Austin on Sec. 31, T. 19 N., R. 13 E., underlying the sandstone which caps the hill and is, we suppose, the base of the Napoleon sandstone.[*]

These uppermost beds are a series of thin bedded, fine grained flaggy slabs, greenish when fresh, deep red when weathered, and contain traces of crinoids, and lamellibranchs. We can trace them in the talus around and down the hill to the southwest, and on the road from Port Crescent they appear somewhat more massive—probably a slightly lower horizon, but the terrace opposite the wave-cut bluff along which the road runs shows a fossiliferous shingle (*Leiopteria torreyi*, Pl. XI, Fig. 2) like that on the hill. Passing next to the shore we find a heavier sandstone and then, some 70 feet below our assumed top, the rocks of Hardwood Point, on Sec. 35, T. 19 N., R. 12 E. These are calcareous flags with Solens, *Goniatites marshallensis*, *Orthoceras indianense*, *Nuculana*, and other characteristic Marshall forms. Close beneath, say from 73-75 feet below the top, the rocks become shalier and very micaceous and pass into a plastic blue shale, then becoming sandier and more charged with carbonates they pass into a series of flags which contain a fauna identical with that of Hardwood Point, and in streaks contain abundantly Solens and bryozoa, and lie over the more massive sandstones of Flat Rock Point. Next below we have the heavy white sandstones of Port Austin, pure or with small quartz pebbles, highly crossbedded in two or three layers, the cross bedding dipping in the top layer 45° toward N. 38° E., in the layer back of Broken Rocks, 25° toward S. 10° E. and around Kimball Island northeast again. Winchell says that the first of the series is a bluish gray sandrock 12 feet thick, followed by a whitish and grayish, sometimes yellowish, fine grained sandstone, very pure and massive, occurring in beds 10 to 12 feet thick, without pebbles or seams, and moderately coherent. The sandstone appears fairly white and clean along shore, but from some outcrops in section 23, Dwight, of coarse red, friable, highly fossiliferous sandstone with pectinoids, *Athyris Cf. ohioensis* and *Centronella flora*, and a small Schizodus at the same horizon, and other indications, it is likely that this pure white sandstone is only the result of leaching. Its total thickness seems to be somewhat over 20 feet; our column makes it extend from 85-107 feet below the base of the Napoleon. The Skene well apparently just misses it. Just beneath it, opposite Point of Pines, and rising into sight by a slight undulation to the east of Broken Rocks are some thin-bedded ripple-marked flags with a narrow band of peanut conglomerate, which are the first beds met in the Skene well. We find Goniatites again and Rominger says *Rhynconella camerifera* (Pl. X, Figs. 11 and 12). The beds beneath appear to be fine grained, not porous to water, and soft (not resisting erosion) arenaceous shales, the only somewhat doubtful exposure being along the beach toward Point aux Barques (Sp. 19204), with coaly bits of vegetation and lamellibranchs.

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[*] For it is at least 68 feet, probably more, above the top of the Skene well, Port Austin, or $68 + 1225 = 1293$ feet above the base of the Berea. Thus as the top of the Napoleon is about $1750 - 120 = 1630$ feet above the bottom of the Berea in the Caseville wells, Sec. 35, T. 18 N., R. 10 E., the sandstone is not probably more than 337 fect below the top of the Napoleon sandstone, and is more likely to be somewhat less, thus bringing it at the base of that formarion. Moreover its topographic position, capping the hill, makes it likely to be the relic of a heavy overlying protecting formation.

The picturesque cliffs of Point aux Barques are the outcrop of a sandstone which may, upon weathering, become white and indurated, but is then probably deprived of cement, is somewhat greenish and pyritic in aspect, and in the lower part may appear red and striped. It is highly cross-bedded, and that fact as well as its general aspect is well illustrated in Plate III.

The thickness of this sandstone may be taken as 18 feet, say from 176[*] to 194 feet below the top of the lower Marshall. Below, the beds become gradually thinner and finer grained, more like the grindstone, with no sharp break. and are exposed in the bluffs just north of the southeast corner of Sec. 23, T. 19 N., R. 13 E., until finally we have a little blue shale, and at 220 feet from the top of the formation[†] narrow seams of calcareous sandstone covered with *Camarotœchia* (*Rhynconella*) *camerifera* and *Romingerina* (*Centronella*) *julia*. This zone is found just north of the road running northwest from Grindstone City, at 1400 paces north and 900 paces west of the southwest corner of Section 26, T. 19 N., R. 13 E., and also on Willow River, and is one of our datum zones. Underneath it come slabby micaceous green flags and grindstones, with blue shale and perhaps streaks of limestone for some 15 feet until we come, at 235 feet, to a band of peanut conglomerate, probably not persistent, which lies on top of the present grindstone quarries on

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[*] From the Skene well 105 feet + 2.63 miles at 27 feet to the mile = 176 feet; similarly from the Carrington well 1330 feet—1198 feet = 132 feet + 9400 feet distance to Carrington's well × dip of 27 feet to the mile, derived from comparing Grindstone City with Port Austin wells = 180 feet.

[†] From the Skene well 105 + 4.3 miles at 27 feet dip per mile.

Sec. 23, whence come the famous whetstones. Fifteen feet below, outcropping near the shore at Grindstone City, seems to be another band, similar but richer in fossils, and the whole thickness of the grindstone beds seems to be about 25 feet, making the thickness of the whole Marshall as we have taken it 560 feet. These last twenty-five feet are generally very even grained, and not generally cross-bedded, though occasionally that defect appears and injures the quality of the stone. Sometimes calcareous concretions, i. e., concretions of sandstone more firmly cemented with carbonates of calcium and iron occur, in which fossils, especially Goniatites, may be found. Fish fragments, both teeth and bones and spines are frequent and the surface of occasional seams is strewn with small fragments of woody matter turned into coal, and of fish teeth, which are also blackened.

The formation as defined is prevailingly sandy, while the one subjacent is prevailingly shaly. Bits of land plants, beachworn and battered shells, Solens and lamellibranchs generally, indicate a littoral facies.

The correlation of the Marshall has been, as previously noted, the subject of much discussion. A list of Winchell's papers has been already given, and he gives an elaborate account of the bibliography up to his time, in the article in Vol. XI of the Proceedings of the American Philosophical Society already referred to. Rominger, as we have said, refuses to attempt any very exact correlations, and raises objections to those of Winchell. These objections are in part well founded, but in part he mistakes, it seems to me, the drift of the argument in Winchell's mind. Winchell appears to me not so much concerned to disprove the Carboniferous character of the formation underlying the Marshall, as he is to reclaim at least the Marshall for the Carboniferous. Late researches would, however, draw the line* nearly where Winchell drew it. Rominger adduces two arguments against dividing the Marshall from the underlying and assigning the former to the Carboniferous, and the latter to the Devonian.† The first argument which is the conformity of rock material and stratification which he cites, though true, is not sufficient, for we know that in many parts of the Mississippi basin, there is a perfect conformity between the Devonian and Sub-carboniferous (Mississippian). The second argument that the underlying forma-

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*C. L. Herrick (Geol. Ohio, VII, p. 510 et seq.).
†Loc. cit., p. 75.

tion presents the faunal characters of the Cuyahoga shales of Ohio is also true, but its weight will depend upon the ultimate disposition of these shales. The latest Missouri reports assign what used to be termed Lower Kinderhook to the Devonian. The more important recent papers for Ohio are by Herrick.*

We find that Herrick subdivides the old Waverly, and assigns part to the Devonian, and part to the Carboniferous. We are able, I think, to make, with the help of Mr. W. F. Cooper, his former assistant, close correlations with his zones,† and thus so determine our strata, that whenever the line between the Devonian and Carboniferous shall be finally fixed in Ohio, which is a question for the general palæontologist, it may be easily extended.

Our section is more complex and thicker than his, and he mentions that the fauna of the first fifty feet of the shale below his conglomerate I contains many Michigan Marshall forms, though his list of freestone fossils seems more akin to ours, even to those of the *C.* (*R.*) *camerifera* zone. His next fauna is obtained largely from calcareous nodules in the Cuyahoga shales, some seventy feet more or less below his Conglomerate I and contains a *Prœtus missouriensis* found at the Point aux Barques lighthouse, numerous Spirifers and an assemblage Devonian in habitus, compared with those above.‡ This lighthouse stratum we make to be some 175 feet more or less below the bottom of the Marshall or about twice as far down as the nodule band in Ohio, but the whole formation down to the Berea black shale we find to be thicker (868 feet) than in Ohio (Geol. Ohio, VII, p. 32; 300 or 400 feet thick), in about the same proportion, so that the base of our Marshall might perhaps be coeval with Herrick's base of Division II, though the Schizodus zone of the lighthouse fauna is more like that of the Waverly freestone as a whole, and Mr. Cooper takes the lighthouse conglomerate to be Herrick's No. I.

Concerning the climate of the Marshall as thus defined we may note, somewhat in contrast to the group lying immediately above, that the abundance of mica and sand, feldspar and small pebbles, shows rapid land waste and rock decay while the abundant bits of vegetation show that there was abundant plant life. Both facts point to a relatively humid climate. The abundance of iron suggests that the land waste was from a region full of basic rocks.

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*Geol. Ohio, 1893, VII, p. 495, et seq., summarizing papers in the Bulletins of Denison University, American Geologist, and American Geological Society. See also Bulletin No. 80, U. S. G. S., Correlation Papers, Devonian-Carboniferous, by H. S. Williams.

†See Chapter X.

‡This fauna has been recognized by W. F. Cooper at Rock Falls with the characteristic nodules.

§ 8. Coldwater shales. (e, 1)

The term Coldwater is nearly equivalent to Winchell's Chemung shales and to the Cuyahoga of Ohio, but as the New York and Ohio names are receiving remodelling, it may be well to cling to the name used in Vol. V, a while longer. Lithologically it corresponds to the Portage shales, for as the formation above is prevailingly sandy though with occasional minor streaks of blue shale, so, conversely, this formation is prevailingly blue shale, with occasional streaks of sandstone, not generally very persistent nor coarse, and when struck under cover salty. Hence as a recent well in Grindstone City shows, not much water can be obtained from it. The base of the bluffs, south of the old grindstone quarries on Sec. 30, T. 19 N., R. 14, shows the top of these blue shales. After about 30 feet the formation is sandier, as found at the top of the New River well.[*] These flags also seem to form the crest of the bluffs south of Huron City. We seem to trace this horizon in the Port Austin well at 204 feet depth, which our computations make 49 feet below the top of this group. Of these sandier beds there are according to the Eagle Bay well (Sec. 23, T. 19 N., R. 13 E.), some 24 feet, according to Rominger some 20 feet on the hill, and then we get blue clay shale again. Rominger recognized (*Nucula*) *hubbardi* therein. Willow Creek, at Huron City, exposes a section about 89 feet below the top of the Coldwater formation.[†]

The lower part is blue shale with compressed lamellibranchs, while the upper part has several sandier seams of dark greenish blue flags, which show their high per cent of carbonates of iron, etc., by weathering very rusty. We measure, beginning at the top:—

6 inches, dirt;

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[*] 1750—1029 = 41 feet; by the Eagle Bay well, Sec. 23, T. 19 N., R. 13 E., 54-78 feet below surface is grindstone.

[†] In placing this section at this point in the column some account is taken of altitude, and a dip is assumed of 55 feet to the mile for a strike of N. 26° W., which dip is derived from comparing Grindstone City and Port Hope wells. The strike is probably veering more to the north and the dip is less in proportion, but so long as we compare two points whose distance apart along the strike is not large relative to their distance at right angles thereto, the error involved will not be great, and checking up on the (*Centronella*) *Romingerina julia* zone where it crosses Willow Creek—it is found near by in the bottom of a well.—we have the position of the Huron City outcrops in the geological column thus determined: 220 (the depth of the *Romingerina julia* zone below the top of the Lower Marshall)—(1.4 miles which is the distance perpendicular to the strike from the outcrop of *Romingerina julia* on Willow Creek to the Huron City bridge outcrop × 55 feet per mile dip)—(the difference in altitude above lake of the two outcrops just mentioned, viz. 60—10)—260 (which is the thickness of the lower Marshall) = 87 feet for the distance of the section above mentioned below the bottom of the Lower Marshall, which checks very well with other computations.

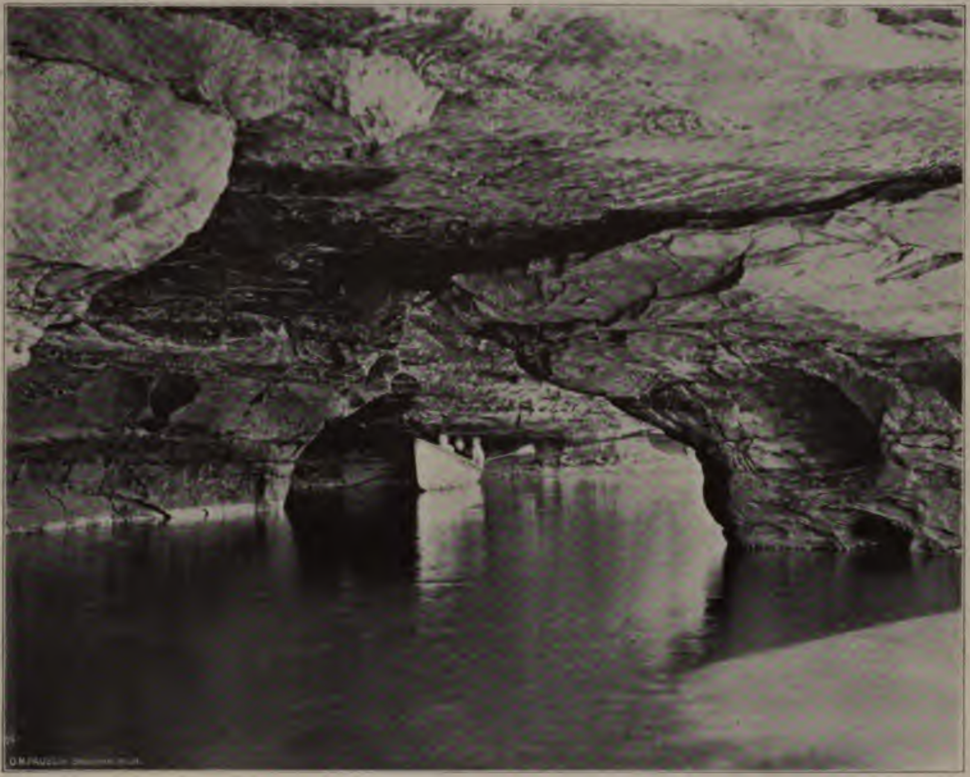

PLATE III.

Illustrates the appearance and cross bedding of the Lower Marshall sandstone at Point Aux Barques; also the undercutting action of the waves and formation of caves.

(Reproduced through the courtesy of the F. & P. M. R. R.)

3 inches, red sandstone seam, with Rhynconella, Sp. 19036, Productus, and Pleurotomaria, Sp. 19039, etc.;

3 inches, barren;

6 inches, sandy;

3 feet blue shale, sparingly fossiliferous; Sp. 19043;

2 feet blue shale; no fossils found.

Below we have arenaceous shales with small seams of sandier nature, fairly continuously exposed until we come to the section given below at the bluffs south of the lighthouse (Fig. 5). I take my section about where the east line of Sec. 11, T. 18 N., R. 14 E., strikes the bluff. Winchell gives slightly different measurements, and his section may have been taken somewhere else. Moreover 40 years has doubtless made a difference in the bluffs, but both sections agree in giving an intermediate portion with a number of seams of sandstone up to two and three feet thick, while blue shales lie above and below. I consider my section of 32 feet to be from 156 to 188 feet below the top of the group as follows:*

A. 11 feet, 3 inches, blue shale;

B. 3 inches narrow band of calcareous sandstone, brown in weathering;

C. 3 feet blue sandy shales;

D. 14 feet 6 inches to 14 feet 10 inches; a compact brown very fossiliferous sandstone, the Schizodus sandstone, which seems to be the principal source of the extensive fauna here collected, Sps. Nos. 19044-19067; at 170 feet from the top of the group;

E. 1 foot 3 inches, blue shale;

F. From 16 feet 1 inch to 19 feet 9 inches, the main bed of sandstone, conglomeratic (pebble of coal!), pyritic, especially the top which is almost a solid layer of pyrite, enclosing and replacing many fossils; at times very calcareous, and again appearing as a white sandstone, the pebbles appearing as small rounded grains of quartz. Sp. 19074 shows the pyritic facies, and Sp. 19068 the conglomerate, and Sp. 19073 the sandstone facies; from 173 to 176 feet from the top of the group;

G. About 12 feet of blue shale to 188 feet below base of Marshall; fossils very rare, but occasional Producti, and Spirifers, and minute forms, (? trilobite larvæ) are to be seen, as illustrated by specimens, Nos. 19076-19084. We may compare the fauna with that

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*From *Romingerina julia* zone (3.05 miles × 55 feet deep = 168) + 220 + 60 (altitude of Romingerina zone) — 260 = 188. Compare Port Austin 336 + 105 — 260 = 181. and Caseville 800 to 900 — 120 — 560 = 120 to 220.

of the *Romingerina julia* zone, etc., and find corresponding forms but in the upper zone they are all smaller.

Winchell's section is given on page 75 of the 1860 report.

Though this stratum is so thin, the richness of its fauna, and its apparent persistence and thickening under cover, if, as seems probable, it is the same as that found at 336 feet under Port Austin, and somewhere between 750 and 800 feet under Caseville, in which event it is very likely still more widely recognizable,[*] make it important, and suggest its correlation with one of Herrick's zones, viz.: Conglomerate I.

Below this the formation grows more and more shaly, with fewer sandy streaks. The outcrops, along shore and south of the mill at Port Hope, of sandy shales, with a fauna like that at Sand Beach seem to be about 283 feet from the top of the formation, and a greenish micaceous sandstone found at 16 feet depth in the Port Hope well may be at 299-305 feet from the top of the formation.[†]

We may place the horizon of the top of the Sand Beach well near 400 feet below the top of the Coldwater.[‡]

At about this point in the column are the greenish and bluish micaceous, more or less sandy, shales of the creeks near Sand Beach with Chonetes mentioned by Rominger, (*scitulus?* apparently *pulchella* Win.) and a little lower, 454 to 464 feet below the base of the Marshall, the section of similar shales and shaley sandstones with Chonetes, Goniatites and a Conularia at Rock Falls may be placed. Similar sections are exposed respectively one mile and 4 miles farther south. This is correlated by Mr. W. F. Cooper with the Moots Run section of Ohio. The fauna all along the east shore seems identical, the Chonetes being the most abundant form. The top of the White Rock well must correspond to about 505 feet of the section,[§] and this determines the approximate place of the clay bluffs of arenaceous shale to the south with the indistinct casts of fossils—Goniatites and the like,—which were mentioned by Rominger. To our search they were unfossiliferous and well exposed in a stream bed. They look as though they would make good cement clays.* The well at Forestville, about two miles south of the county line, encounters the Berea at 465-505 feet down and hence its top may be placed at a horizon about 555 feet below the top of this group. But the blue arenaceous shales continue without material change until within some 100 feet of the Berea grit and hence are the lowest rocks outcropping in the county. The rest of the column, Plate I, is only struck in the deeper wells, but to get the full thickness of these bluish green shales we must add to the 396 feet above the Sand Beach well, 500 feet more recorded in the upper part of that well, making 896 feet. Lithologically the rock is equivalent to the Cuyahoga group of Ohio and the shales of Branch county in this State, and is the counterpart of the Portage group of New York, with its sandier beds above and black shales, etc., below, but lying farther westward it doubtless represents a later time when the Michigan part of the continent was undergoing a similar stage of development to that which occurred earlier in New York.

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[*] Vol. V, Pt. II, p. 20.

[†] 1750 — 787 — 680 = 283, or 1680 — 716 — 680 = 284, comparing the Port Hope and Caseville wells, or comparing the Port Hope and New River, 1029 — 787 + 41 — 283, in each case + 16 feet for depth in well.

[‡] The reports as to the depth of the Berea in this well vary a good deal; a place for the top of the well 368 feet below the base of the Marshall is obtained by correlating 702 feet Sand Beach well with 1750 feet Caseville. Wright's figures, 715, would give 355. Similarly correlating Port Hope 716 with 633 of Sand Beach gives 366 feet, or with 603 feet gives 396 feet, while comparing 787 with 664 would give 406 feet. 664 feet seems to be the more precise figure for the depth of the base of the sandstone in the Sand Beach well, which would make the horizon of the well 406 feet down in the coldwater shales, but it is doubtful if in other wells some 10 feet or so below the sandstone has not also been included in the depth.

[§] The depths to the different horizons in this well are also variously given. We correlate the bed at 555, White Rock, with that at 664, Sand Beach, making the former 109 feet the lower. If the depth should more correctly be 550, White Rock, we should have the top of the White Rock 114 feet below the top of the Sand Beach well and correlating the top of the Berea, 450 or 495, with 633, of Sand Beach, we

§ 9. Formations not exposed at surface. **Berea shale** (e, 2).

The Sand Beach well gives from 600-603 feet as black shale, with a few feet more of transition, above the Berea grit. The "rotten bad-smelling soft rock" from 800-900 feet of New River doubtless represents the same horizon, and the dark blue shales of Port Hope, from 533 feet down, and the 40 feet of chocolate colored shales above the Berea in the Port Austin well may mark the same horizon. In the Caseville wells it is not reported, but should come, according to our data, from 1548 feet down to the Berea, say 102 feet. This is probably rather more than it really is, though it doubtless exists there, for we find it recognizable in Bay City. But the less we make it, the more we must make the overlying Cuyahoga.

Berea grit (f).

It will be noticed that we assume this famous producer of oil and gas and brine to have been struck in almost all the wells that have been put down for salt, and from it we have computed our funda-

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have similarily 117 feet or 183 feet for the difference in horizons between the tops of the wells, while a correlation with the bed at 1225 of the Port Austin well of the bed at 555 feet at White Rock, would give the top of the White Rock well as 142 feet below the horizon of the Sand Beach.

*See Vol. VII, Part I, by H. Ries, for views of and reports of tests on these clays. See also Part III of this volume, on Sanilac county, Plate III.

mental dips. That we are justified in correlating the wells in this way is shown, (1) in some cases by the correspondence of other strata, the Berea shale, the lighthouse sandstone horizon, etc., (2) by the correspondence in the character and thickness of the rock itself, which has been so repeatedly pierced, at such short intervals that there can be hardly a chance for it to escape, as shown by the following succession:

Forestville, 465-505;
White Rock, 495-555;
Harbor (Sand) Beach, 603-664?;
Port Hope, 716-787;
New River, 929-1029—(well penetrates the shales a few feet);
Grindstone City, 1010-1080;
Carrington, Port Austin, 1198 (1100-1200);
Learned, Port Austin, 1160-1225 (well penetrates the shales a few feet);
Hazard, Port Crescent,—1250;
Crawford, Caseville, 1650-1750 (the figures for the base at Caseville vary from 1735 to 1770);
Bayport, 1900 + ? (not reached).

(3) We have also the indirect but most convincing argument that the assumption of this continuous stratum, makes all the other wells and outcrops fall into place as a consistent whole, while the dips derived from this correlation check with those derived independently. (4) The quality of the brine is uniformly better than in strata above or below.

The rock is almost invariably reported as a white, gray or brown sandrock with a plentiful supply of brine. The more reliable measurements show a thickness less than 100 feet, but so near it that in round numbers that figure is generally given. We make it in our column 70 feet.

Only three wells have penetrated deeper than this stratum. From the Caseville well all we learn with any degree of certainty is that between 2200 and 2300 feet, most probably at about 2270 feet, it struck another brine more impure than the one they had been using. The chances are that this is in the top of the Traverse or Hamilton group. So we continue our column with the aid of the Harbor (Sand) Beach well.

Ohio shale (Saint Clair, Huron black, or Black). (g)

(1.) *Bedford shale.* Below the Berea we have in the Sand Beach record 186 feet of light colored shale. In the White Rock record, however, there is given a three foot stratum of gaseous black shale, which if we take it to be the Cleveland shale would then leave about fifty feet above it to be assigned to the Bedford. This we will accordingly do, and this thickness corresponds very well to that assigned to the Bedford shale by the Ohio geologists.

(g 2.) *Cleveland shale.*

The narrow belt of gaseous black shale of three feet between 600 and 610 feet, in the White Rock record is at the proper place in the column for this shale.

(g 3.) *Erie shale.*

The underlying light colored shales, for the remainder of the 186 feet (186 — 53 = 133) through which they occur in Harbor Beach well, may be assigned to the Erie shales, being of the proper color and position. It is highly probable, however, that these alternations of blue and bituminous shales are very inconstant. Still, the Bay City record shows a somewhat similar group in a similar place.

(g 4.) *Huron shale.*

The next 270 feet from 850-1120 of the Harbor Beach well is said to be a dark brown or black slate, which corresponds very closely to Newberry's Huron shale, is the great Devonian Black shale, and is one of the most widespread of lithological datum-planes.

Traverse group (h).

We next have, from 1120-1725, some 605 feet of light slate or "soapstone," i. e., calcareous shales, with 15 feet of extremely hard rock at 1400 feet. This appears to be the Traverse group, which has already thickened enormously, judging purely by lithology, from what it is in the southern part of the state, but this thickening is a characteristic of our column generally. Somewhere in this series which is 456 feet and more below the Berea, the deepest Caseville well may be supposed to obtain part of its brine.

At 1400 is a belt of extremely hard rock, probably a cherty limestone, possibly a pyrite nodule, a premonition of what we are to find below.*

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*The "granite" in the Churchill well at Alpena, from 145-153 feet down, seems to correspond. It may be the horizon of the Encrinal limestone.

Helderberg limestones (i, j).

At 1725 feet we seem to have reached that series of limestones which lie at the base of the Devonian and top of the Silurian. At 1844, 119 feet below, where it seemed to be lime and sand mixed, we may possibly be near the horizon of the Oriskany or perhaps the Sylvania sandstone, but the limestones were penetrated 86 feet farther down, to 1920 feet, the rock growing coarser, dolomitic (?). If we may venture a prediction, some 500 feet farther down—2400 feet—would carry the Harbor Beach boring well down to the rock salt formation struck in the deep wells at Goderich, Canada, and in the deep wells of the Saint Clair River. It would probably be not less than 1300 feet farther down to the Trenton. We thus finish our geological column, or account of the rocks of the county in descending order. It may be remarked in conclusion, that since the thickness of the beds varies from point to point, no such column is exactly accurate anywhere. We have tried to make ours fit as closely as possible to the section as it might be found by a shaft at Caseville. It must be remembered, however, that for the Marshall and the formations generally the coast of the adjacent land was to the northeast, so that as we go to the southwest there will be less variety and in general less thickness to any division of our geological column.

The plate of our Geological column, Plate I, which may be compared with Plates VI and LXXIII of Vol. V, and uses the same symbolism for the lithological character of the beds, is constructed by combining the record of the Sand Beach well below the Berea, with that of the Caseville well, filled in with local observations, as far up as it goes, then using the record of the Bayport quarry's deepest boring, and finally that of the Bauer well at Sebewaing, thus covering the whole of the column in as great detail as possible, consistent with any accuracy in summation. It is obvious in construcing the column in this way that if for instance we have overestimated the thickness of the Napoleon sandstone beneath Caseville, we shall have to increase some other formation by the amount that this sandstone is in excess and similarly in other cases.

CHAPTER III.

PHYSICAL GEOGRAPHY OF HURON COUNTY.

§ 1. Introduction. Relation of physical geography and geology. Physical geography and geology are kindred sciences, in fact inseparable. Physical geography is the geology of the present, while one branch of geology is the physical geography of the past. But as the biography of a man usually and rightly begins with some account of his ancestors, so we can only understand physical geography rightly when we have some idea of the origin of the present forms of the earth's surface. On the other hand we use the present as the key whereby we may unlock the past. One of the marked features of the last decade is the expansion of the science of physical geography under the influence of geological ideas, and a correlative development of geology, which now endeavors to read the history of the carving of the land surfaces of the earth, as well as the history of the filling up of its sea bottoms. No farther apology is needed for introducing some account of the physical geography of Huron county into this report. I trust it may aid the teachers of the county to make their instruction more real by the introduction of familiar illustrations.

We have already described the general location of Huron county as lying at the end of a peninsula, bounded on the one side by Saginaw Bay and on the other by Lake Huron (Pl. VIII). The effect of the neighborhood of so much water in mollifying the climate is plainly to be noticed. This advantage it shares with Michigan generally and the subject has been quite fully developed by A. Winchell.* His climatological maps show that in January the temperature is about 24° to 25° F., and in July 68° to 69° F., i. e., some 3° warmer in winter and 3° colder in summer than in the middle of the state, and some 6° warmer in winter and 6° colder in summer than at a corresponding latitude in Minnesota. These figures are sufficient to show the effect of the lakes in producing a semi-insular climate, while the effect in checking extreme temperatures for few hours, e. g. frosts, is yet more marked. For example, the first autumnal frost at (Sand Beach) Harbor Beach in 1894 (the latest date conveniently accessible) was on October 12, while in Adrian, Lansing and Howell it was September 25, and most of Indiana was visited by frost before October 12. The mean annual temperature would be according to Winchell's maps a trifle under 45°; from 1899 to 1900 it averaged 46.0° at Hayes, 44.4° at Harbor Beach, and the weather service data furnished to U. S. G. S. paper No. 30 make it the same. This is practically the same temperature which obtains at points at a corresponding latitude on the great plains. We see thus that the effect of the lakes is to check oscillations and extreme variations of climate, rather than to change the average temperature for the year.

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*1871. Harper's Monthly, XLIII. p. 279, 281; also Walling's Atlas.

The following reports furnished us by C. F. Schneider, director of the State Weather Service, show the temperatures and precipitation for the past ten or twelve years in two stations within the county, and agree probably as well as observations of short period and of thirty years ago could be expected to, with Winchell's results.

PRECIPITATION AT HARBOR BEACH (SAND BEACH), HURON COUNTY, MICHIGAN. OBSERVER: W. NIMS TO FEBRUARY, 1896, SINCE THEN N. P. ARNOLD.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1887	......	......	......	......	......	3.66	1.66	1.49	1.16	3.22	1.13	1.89	......
1888	0.48	0.50	......	.....	......	......	1.30	3.44	0.76	......	......	0.40	......
1889	1.98	1.39	0.30	0.85	3.23	5.59	1.81	1.92	0.89	0.97	......	3.25	......
1890	1.41	2.34	0.72	1.86	3.30	3.34	4.27	3.40	0.82	7.37	2.54	2.60	34.93
1891	2.40	1.80	2.02	1.45	0.52	0.66	2.96	4.85	1.92	2.08	6.03	2.01	28.20
1892	6.27	1.85	1.20	1.08	2.61	3.55	1.72	2.86	4.77	3.46	2.95	2.02	34.34
1893	1.20	3.90	1.51	4.14	4.25	2.13	2.02	2.17	2.05	5.94	2.57	2.90	34.77
1894	......	......	1.95	1.82	4.11	4.48	1.10	0.77	3.12	3.37	1.32	0.90	25.40
1895	......	......	......	2.10	2.14	0.96	1.02	3.60	3.43	0.77	2.31	2.87	19.20
1896	......	0.38	0.35	1.49	2.73	3.72	0.93	3.99	5.56	0.62	1.50	......	21.27
1897	......	......	2.30	35.4	37.4	0.79	3.02	2.56	0.83	3.07	1.50	2.55	23.90
1898	1.30	1.40	1.85	2.27	1.82	4.19	0.20	3.89	1.05	3.98	3.08	0.67	25.70
1899	1.41	0.95	2.47	0.88	3.22	3.14	2.05	0.19	2.84	3.09	1.63	2.16	24.03
1900	0.60	2.37	2.25	1.65	2.11	......	......	......	......	......	......	......	......
Mean	2.06	1.61	1.47	1.95	2.88	3.02	1.83	2.91	2.20	3.17	2.49	2.01	27.98

TEMPERATURE: SAME STATION AND OBSERVER.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average.
1887	......	......	......	......	......	64.2	74.2	66.2	59.4	45.1	36.0	28.9	......
1888	16.3	21.4	......	......	......	......	68.0	67.0	59.1	......	......	31.8	......
1889	27.6	16.5	32.3	41.6	51.8	57.2	69.0	66.4	62.0	43.8	......	34.6	......
1890	27.9	27.3	24.8	39.8	47.5	64.8	66.8	63.7	56.6	46.4	37.6	24.1	44.0
1891	26.8	26.5	26.0	41.8	48.8	60.5	62.7	64.7	61.6	45.6	32.4	29.3	43.9
1892	15.6	21.8	23.7	......	48.4	63.5	65.7	64.3	61.2	49.6	35.8	24.8	43.1
1893	14.5	17.6	29.3	39.6	49.5	64.0	68.7	67.0	59.6	52.6	35.4	24.7	43.6
1894	26.0	21.7	39.1	43.0	50.7	66.2	70.6	67.4	64.0	50.2	33.2	31.8	47.3
1895	19.4	15.9	24.0	40.0	56.5	65.2	64.5	65.8	63.6	44.5	36.1	28.7	43.7
1896	23.2	23.2	26.2	......	60.2	61.9	68.6	68.6	58.0	50.1	......	28.2	46.8
1897	23.0	27.2	29.0	40.2	50.4	56.0	67.0	63.2	62.2	51.6	36.6	25.4	44.3
1898	24.0	20.8	33.3	39.0	52.0	63.4	69.4	67.4	63.4	50.9	36.2	26.1	45.5
1899	21.0	16.4	24.3	42.8	53.2	63.0	65.6	67.9	57.4	52.8	41.7	27.4	44.5
1900	25.6	18.5	23.0	43.0	54.0	......	......	......	......	......	......	......	......
Mean	22.1	21.4	28.4	40.9	51.7	62.5	67.9	66.0	60.9	48.3	35.5	28.2	44.4

PRECIPITATION AT HAYES, HURON COUNTY, MICHIGAN. OBSERVER: C. F. LEIPPRANDT.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average.*	Total.
1889	......	1.40	......	......	......	......	......	......	......	......	2.59	3.36	......	......
1890	1.41	1.00	0.98	1.61	3.47	......	2.17	2.86	0.28	4.98	2.02	1.46	2.04	24.47
1891	......	3.50	1.70	......	0.84	......	1.49	9.47	2.91	2.17	......	0.60	2.32	27.82
1892	2.50	......	0.30	......	2.45	4.84	......	2.32	......	1.18	1.57	1.61	2.08	24.96
1893	2.90	2.50	1.40	4.35	3.36	1.25	2.65	1.13	2.11	2.76	......	2.95	2.44	29.25
1894	1.14	1.22	1.70	1.60	3.77	1.27	2.06	0.14	3.11	2.17	......	0.50	1.67	20.07
1895	4.23	0.60	0.80	1.15	3.08	1.18	2.15	1.93	2.60	0.80	1.86	2.36	1.89	22.74
1896	0.94	0.78	......	1.25	2.14	0.78	0.67	2.44	6.05	0.85	2.28	0.46	1.71	20.48
1897	3.93	1.09	3.80	3.08	4.09	2.23	3.74	1.53	1.13	2.72	1.83	1.51	2.52	33.24
1898	1.84	1.82	2.36	1.44	2.00	3.27	1.01	3.57	1.26	5.20	1.09	0.32	2.09	25.18
1899	0.90	0.70	3.54	0	2.66	3.00	3.73	Tr.	2.91	3.19	0.75	1.11	2.304	......
1900	0.68	4.68	3.00	1.11	3.10	......	......	......	......	......	......	......	3.22	......
Average	2.21	1.46	1.84	1.81	2.79	2.23	1.99	2.82	2.43	2.54	1.89	1.51	2.16	25.88

* Average per month or total per year in feet and decimals of a foot.

TEMPERATURE: SAME STATION AND OBSERVER.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Average.
1889	......	......	......	......	......	......	......	......	......	......	39.2	35.6	......
1890	30.3	30.5	28.3	45.6	54.0	68.4	68.4	63.2	57.6	48.1	39.5	26.7	46.7
1891	26.5	......	29.5	49.4	53.3	64.4	66.0	66.4	63.6	46.8	......	35.5	46.7
1892	19.2	......	29.2	......	52.0	66.5	......	66.7	......	49.0	35.3	25.9	45.0
1893	13.8	17.1	27.9	41.0	52.5	68.4	68.2	65.8	59.0	52.1	37.7	26.2	44.1
1894	27.1	21.3	40.0	44.5	54.1	67.4	68.5	63.4	62.2	54.2	......	32.2	47.7
1895	17.8	15.2	24.6	43.2	56.4	70.8	69.4	66.0	67.4	44.4	36.3	27.8	44.9
1896	24.6	23.7	27.2	49.2	61.7	65.6	70.8	69.2	57.0	46.7	39.4	27.8	46.9
1897	24.2	26.1	30.4	42.0	52.8	64.2	70.8	66.6	64.2	52.8	36.6	27.0	46.6
1898	25.0	21.6	36.3	41.7	54.4	63.9	67.5	65.6	63.4	49.6	36.3	26.2	45.8
1899	22.0	15.0	22.8	44.0	57.6	66.0	67.8	67.2	58.4	49.8	40.4	27.9	44.9
1900	24.3	17.2	22.0	44.4	56.2	......	......	......	......	......	......	......	......
Mean	23.0	21.3	29.6	44.5	54.9	66.6	68.7	65.9	61.8	49.3	37.5	29.1	46.0

When only two or three months are missing from a year, the yearly average has been found by using the means for the missing months. The general average is the average of the monthly average, and is liable to vary slightly from the average of the yearly averages. Hayes is, I think from its position, a truer representative of the county in general.

The prevailing winds are westerly, though they are modified by the usual system of land and lake breezes, by which in the summer time, on the afternoons of hot days there is a tendency for the heated air over the land to rise and draw in a cool breeze from the lake. A rider on a bicycle quickly notices a head wind and it was quite noticeable that in riding back to Port Austin in from the south after a hot day, one was very liable to encounter a head wind.

In accord with the prevailing west wind the prevailing surface drift of the Great Lakes is eastward, as is indicated on the chart of the Great Lakes issued by the weather bureau. This general character of the lake currents and winds seems to have a marked effect on the character of the shore lines, making those facing west seats of deposit, and accelerating erosive action on those facing east by removing the debris of erosion. This is well illustrated on Lake Michigan, where the shore from Evanston to Manitowoc is eroded away at an average rate of about 5.28 feet a year,* while around New Buffalo, and thence north the sand is piling high. The The same antithesis may be observed between the two sides of Huron County, as will be later seen.

§ 2. Level of Lake Huron.

The level of Lake Huron varies in a very complex way. Eliminating the waves of various causes which are of reasonably short periods, we find fluctuations, dependent either on the direction of the wind which may cause a very noticeable rise of level lasting over a day or two, or on the height of the barometer or on the tidal attraction of the moon, and also on the general relations of rainfall, freezing and evaporation.

Other causes, change in earth level, downcutting of outlet, etc., may have their part in affecting this level. Before we can consider these latter causes which will take us back into the realm of geology almost before we know it, we should consider what fluctuations we really have, and how far they may be accounted for by climatic considerations. Plate IV shows the effect of the fall of lake level from 1886 to 1896 in the line of undermined but deserted cliffs. This inquiry is of great practical consequence, as affecting the depth of harbor improvements, etc., and also as affecting the use of the lake as a datum plane in leveling.

Plate V below, compiled mainly by Mr. M. L. Fuller, under my direction, shows the variation of the lake level during the past century fairly completely. We are indebted to Mr. Charles Crosman for permission to extract a large part of it, viz., from 1858 to 1887, from his chart. We have brought this down to date by appending the records of the Sand Beach (Harbor Beach) gage in the Annual Reports of the U. S. Engineers, and added the earlier part from data in Foster and Whitney's Report on the Geology of the Lake Superior Land District, 1851, Chapter XIX, on the observed fluctuations of the surface of the lakes by Chas. Whittlesey. This quotes from Douglass Houghton's observations in his early reports of the Michigan Geological Survey in 1839 and 1840, so that we are but continuing researches begun by the first Geological Survey. We have also used some data from the Lake Survey.

A comparison of the recorded fluctuations of the monthly mean water level as shown in appendix SS of the Annual Report, upon the Surveys of the Northern and Northwestern Lakes,† shows that

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*E. Andrews, Trans. Chicago Acad. of Sciences, 1870, Vol. II, quoted by Crosman.
†Annual Report of the Chief of Engineers, 1882.

the fluctuations are within a small fraction of a foot the same at Milwaukee and Sand Beach, and at Point aux Barques, and Port Austin. The records are from 1859 to 1882. See also § 5.

In the 18th Annual Report of the U. S. Geological Survey, Part II, p. 624, the altitude of the Port Austin gage was studied by G. K. Gilbert of the Survey to determine if there was any relative change of level, i. e., any elevation of the land. He chose a period in July and August, 1876, when the weather and wind were not likely to produce local disturbances of level, to compare it with the gage at Milwaukee. He found that the Port Austin gage zero, which was about 7.4 feet above the water level was on the average 5.21 ± probably .013 feet, above the Milwaukee gage, which was about 2.2 feet above the water level. This Port Austin gage zero was originally placed on a level with the main or Wisner benchmark (590.53 A. T.), but Gilbert says that Mss. records of the Engineers office state that in July, 1875, it was 0.003 foot too low and on Oct. 18, 1876, it was 0.040 too low, having settled in the meantime. As the readings studied by Gilbert were during the time of settling he was obliged to apply a correction, which he took to be 0.034 foot, but applied in the wrong sense and found the gage zero to be 7.460 above a check point at Port Austin, to wit, "the top of an iron bolt driven into a vertical face of bed rock on the west side of a promontory opposite the residence of J. W. Kimball," i. e. 590.570 A. T. instead of which it should be 7.39 above the check point (590.50 A. T.). Mr. Gilbert had a new series of observations made at Milwaukee and Port Austin in the summer of 1896, with the help of Mr. John P. Smith of the Port Austin News, using a new gage which he established with its zero 5.125 feet below the check point (577.985 A. T.), and about 1.2 feet below the water level of that time. Assuming the lake level to be the same at Milwaukee and Port Austin he found as the result of a series of readings that the gage zero was now 6.875 feet ± 0.019 foot below the Milwaukee gage zero. Correcting and tabulating his results we have:

	1876.	1896.
Mil. check point above Mil. gage zero	0.843	1.205
Mil. gage zero above or below Port Austin gage zero	—5.210	6.875
Gage zero above or below check point, Port Austin	7.390	—5.125
Check point at Milwaukee is above that at Port Austin	3.023	2.955
Difference	0.068 ft.	....

which is what Port Austin has risen relative to Milwaukee in the last 20 years, a quantity within the range of possible though not of probable error. The slip of the gage in 1876, which seems to be the most uncertain element, could not make the result more than .006 foot less and if all the change took place after August, 1876, the elevation would be greater.

Prof. Gilbert concludes that the land is rising to the N. W. at a rate that would produce an apparent fall of the lake in Huron county of 0.2 foot per century.

It may be worth while some time to test some of the other bench marks left by the Lake Survey, to wit:

Bench mark near Station D at the mouth of Willow River was 5.65 feet above mean water level in June, 1857.

On overhanging rock near Station No. 30, Point aux Barques, 16.8 feet above water surface in 1857.

Bench near triangulation station M, Partridge river was 5.3 feet above water surface in 1857.

Bench mark 300 feet east of triangulation station L is marked with a cross on the top which is 9.6 feet above mean level of water surface for season of 1857.

In the curves of lake level fluctuations published in the report of the Chief of Engineers, U. S. A., e. g. Appendix SS in 1882, the plane of reference for water levels on Lake Huron is taken by assuming that during the months of June, July and August; 1874, the waters on Lakes Huron and Michigan were level and that the high water of 1838 was at either Port Austin or Milwaukee at the same distance above that level.

The Point aux Barques curve was adjusted to the others by assuming that during June, July and August, 1860, Lakes Michigan and Huron were at the same level.

In studying the records plotted in Plate V we see plainly that there is an annual fluctuation of about a foot to a foot and a half.* The effect of the melting of the winter snows, and the spring rains is not fully felt in making the maximum of high water in Lake Huron until June or July. From this time, under the influence of the increasing evaporation and the shrunken inflow due to midsummer heat, the lakes dwindle and their levels fall. The approach of autumn with its cooler weather checks evaporation, the autumn rains begin and the fall is checked somewhat, but is resumed, as Mr. Fuller suggested to me, when the ground freezes and rain changes to snow and the lowest water is in the latest winter months.* Beside this annual fluctuation there is also one of greater period, dependent upon the mean rainfall of the previous years, but lagging behind the rainfall curve. Thus the high waters of 1876 and 1886 were both coincident with periods of extra rainfall. Again, in the earlier part of the century, "from the low water of 1810 to the high water of 1814 there fell in Pennsylvania 34.54 inches of rain more than from the years from 1815 to 1819." So too, the rainfall of the 11 years prior to the flood of 1838 is very large, averaging 41 inches per annum or 11 inches per annum greater than that of the preceding low water of 1819. The signs of the fall of water level since 1886 were in 1896 everywhere evident along the coast. Around Bayport the slope of the land is so gentle that some 400 feet had been added to the shore of Wild Fowl Bay for quite an extent. North Island was joined by a neck to an islet northwest of it, and northwest of Point aux Barques Gull Island had developed from a shoal. The water is said to have been somewhat higher in 1896 than in 1895, and was distinctly higher in 1897. Trespassing a little farther into the past, Mr. Webber informs me that having occasion to have Sec. 17, T. 17 N., R. 10 E., on the shore of Wild Fowl Bay resurveyed in 1895, the surveyor found the meander stakes as called for by the notes of the old Government Survey to be just at the water line. The water was lower than normal in 1895 and in the head of a bay near the mouth of a stream like Mud Creek one would expect to find the shore built out, if anything, so that such observations would indicate no considerable rise of land on lake. We hear indeed of traditions from the Indians around Saginaw Bay, of a time when the Indians could go with their canoes where it is now dry land, but a high water like that of 1838, nearly 6 feet above the recent low water, would give abundant opportunity for such a tradition, when we consider also the out-building of the coast by the accumulating sand, and the extremely gentle slope of the land. On the other hand while the water was in 1896 abnormally low, and we may expect to see it rise again, the water during the summer of 1883 to 1886 was extra high, so that we need not expect it to return to that level permanently. Moreover the last report of the Chief of Engineers, for 1899 (Appendix DDD, p. 3858) reports that the head of the St. Clair has scoured materially since 1867. The indications are that this deepening started about 1887.

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*Crosman says 1.34 ft. See also article by A. J. Henry, National Geographic Magazine (1899), Vol. X, p. 404, and Lieut. Col. H. M. Chittenden, Transactions Am. Soc. of Civil Engineers, Vol. XL (1898), No. 839.

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*Low water is later in Lake Superior, March having the lowest average level, and high water is not until August or September.

The fluctuations of the water level are one of the sources of embarrassment in obtaining very exact altitudes in the county or preparing a contour map, which is the subject of the next section. Before leaving the present subject, however, we must allude to the theory of Spencer,* who, while he also believes that in the more remote past the lake has subsided, believes that at present it is rising again. If there had been any considerable rise of the lake, there would be a tendency to flood the river valleys and lower their grade, causing them to build up near their mouths. Any marked effect of this sort in Huron county is inconsistent with the rock beds of Allen Creek, Willow Creek, Pinnebog and Shebeon rivers, close to their mouths. In counties farther south such flooded river valleys are plainly visible. During the past few years many wells that once flowed, have been ceasing to flow, and in general the water level in wells has lowered. This fall may be due to the settling up of the country, clearing the forests and draining the swamps, and allowing the water that falls upon the surface to run off more rapidly, and also in part to the greater demands upon it by the more numerous wells, and may also be due to such local causes as the draining of the coal mines, but it must also be affected by the unusually dry weather of the past few years. The accompanying fall in the lake level is but an index of the general lowering in ground water level, so that it would not be surprising if the water level in the wells rose again somewhat in the next few years. There are also more temporary fluctuations of the ground water level or head peculiar to individual wells which seem to correspond to the more temporary fluctuations of lake levels. (See Chapter VI.)†

§ 3. Types of shore line.

When we study the shore lines of Huron county we find three different types, which though more or less intermingled, nevertheless predominate respectively on the western, northern, and eastern sides, and depend partly on the slope and nature of the shore, and partly on its relation to the currents and waves.

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*Popular Science Monthly, June 1896.

†This section was written in 1897. There has been no chance to see how much the recent rainier seasons have raised the level of the ground water.

(a). The first type, the mud flat type, is pronounced along the shore from Sebewaing up to Sand Point (Point Charities). The slope of the land surface is so gentle that the force of the waves is thoroughly broken ere they reach the shore. There is, therefore, little beach ridge or crest, though the spring ice may shove up and strand many boulders. The contours of the land sweep out under the sea with scarce a break at the shore line. The prevailing wind and currents beat back the mud brought down by the streams against the shore and the reeds and sedges creep out over the muddy flats and catch both it and the driftwood that is brought on higher stages of the water. The winds blow back into "dunes" the sand from the shore and thus little by little the land creeps out in a series of mud flats or swamps and low sand ridges.

(b). The second type, the sand beach type, occurs all along the shore at intervals, but is dominant from Sand Point to Hardwood Point close to Port Austin. From it the town of Sand Beach, now Harbor Beach, took its name, as being, so it was said, the first appearance of this type of shore line from Port Huron north on the west side of the Lake. This type of shore line occurs (Plate IV) where the water deepens more rapidly, allowing the waves freer action so that they wash away the mud from the beach, while the sand is piled up. Where such shores face the west the prevailing west winds catch the sand and throw it back above the reach of the waves, where it forms rolling ridges of shifting sands "dune sands" for these rolling, wind-built sand hills are called "dunes" and are admirably developed from Port Austin to Port Crescent, and thence to Caseville, and in fact at intervals, all along the western shore. The prevalence of this shore type on the northwest coast is due partly to the supply of sand furnished by the underlying rocks, partly to the more open sweep of water, and partly to the prevalence of on-shore winds.

In this type of shore line the land is not gaining so rapidly on the sea, though it is probably gaining somewhat, but it is the favorite type of shore line where the lake is evening off the irregularities of the land, cutting the points and filling in the heads of the bays and coves. Plate IV is taken from the bay between Point aux Barques and Burnt Cabin Pt.

(c). The third type may be called the cliff and shingle type. It alternates with the second type, but grows more and more promi-

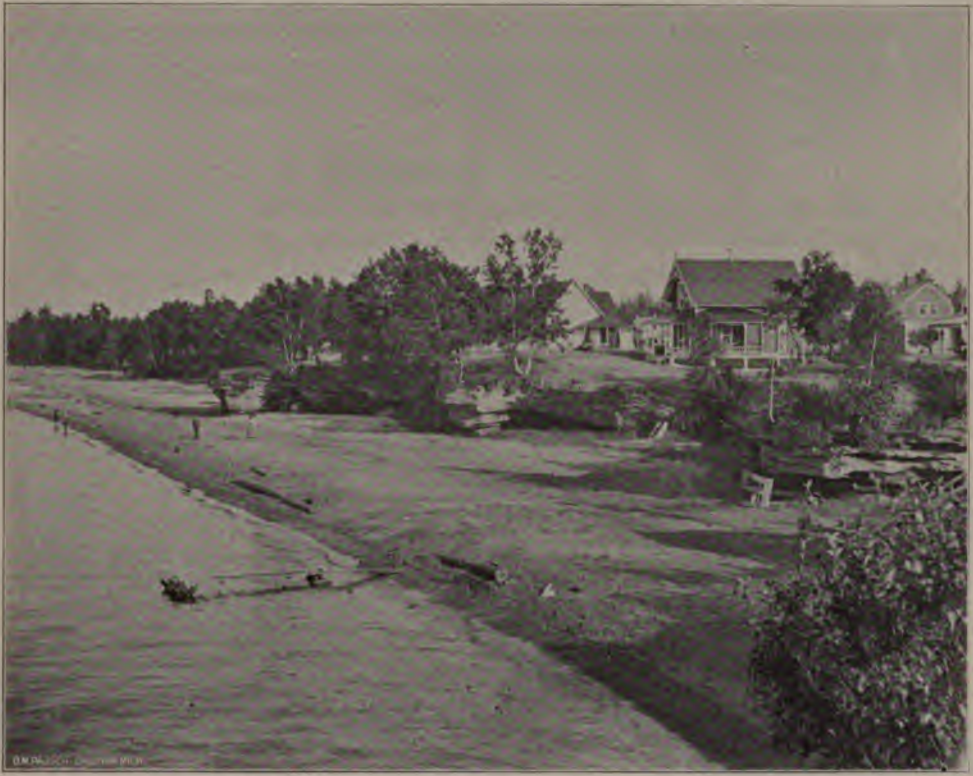

PLATE IV.

Illustrates the transition from the cliff and shingle to the sand beach type of shore line at Point Aux Barques; also the resemblance of the cliffs to boats drawn up on the beach; also the undercutting action of the waves, producing sea caves now abandoned by the water; the top of the cliff is the level of the Algonquin terrace.

(Reproduced through the courtesy of the F. & P. M. R. R.)

nent toward the southeast. In this type there are unmistakeable signs that the lake has been wearing the land back, making cliffs which rise up to 40 feet high, and face a bench made largely of their own debris, and in general more stony than the sand beach type proper, though if the rocks are sandstone, the transition to the second type is easy. For example, Plate IV might illustrate this type, except that the beaches in front of the cliffs are quite pure sand. The third type is typically represented near the Point aux Barques lighthouse (Fig. 5), and around Grindstone City. The stony beach deposit in front of outcrops of rock, composed of fragments torn off by waves, is called shingle. Often such a bench is strewn with boulders. These are perhaps in part as suggested by Spencer boulders left by the washing of the finer part of the boulder clay deposit, but are undoubtedly very largely left stranded by the melting of the spring floes of ice. We are informed that at the Oak Grove resort near Sebewaing they picked up all the stone from the beach one year, but the next year a broad winrow was piled in by the storms breaking up the ice. The ice in the bay is even now often four feet thick, and the stones left by melting are often bigger than a man can carry, even, as reported up to a ton weight. Such observations throw considerable light upon the rapidity with which the beach accumulations may be formed, and upon the depth below the water level at which such boulder benches may be formed. It may be noted that since the lakes are lowest in winter, such large stones frozen into the ice will be subject to a powerful lifting action when the water level is raised by the beginning of the spring rise. The level of the boulder bench in front of Port Austin seems to be four to six feet below present summer water level. Houghton noted concerning White Rock that it was "about 20 feet in horizontal dimensions and 8 feet high with crust on top; it is cracked in all directions, and pieces lie all around it; water 5 feet deep; siliceous limestone and probably a boulder; distance from shore 1,900 feet." In the original Lake Survey sheets this is given as 1,460 feet from shore in 6 feet of water.

On the eastern shore the winds and currents and spring ice help to bear away part of the material which the waves have beaten from the cliff, and thus prevent them from being clogged in their activity as they are on the west and northwest, while the coarser shingle left behind serves as a weapon for new onslaughts.

The contrast thus emphasized between the shore facing west, which is in general growing, and the shore facing east which has been in general retreating, is like that already mentioned in § 2 as also occurring around the lower end of Lake Michigan. While an elevation of land to the northwest and a relative down sinking to the east might accelerate this contrast between the east and west sides by making deeper water and hence more forcible waves on the east side, and vice versa, it seems probable that the lake currents and prevailing winds have been the determining influence.

§ 4. Explanation of contour map.

We find the features of the present shore lines repeated at higher levels, repeated in such a way as to assure us that although the lake has not fallen appreciably during the period of accurate records, yet it has fallen in recent times. Basing our division partly upon the modification of the surface and soil thus produced, but also upon other facts, we may divide the county into four districts, topographically distinct, but before we begin to describe them, we must first explain the contour or topographic map (Pl. VIII), which we shall use in the description.

As we have just said, in 1896, Lake Huron had been retreating. Imagine the process suddenly reversed, and the lake suddenly raised ten feet and the new shore line marked upon the map. Suppose the lake raised ten feet more, and the resulting shore line marked upon the map of the county. Such lines would be called contour lines, and all points of a given contour line are obviously at the same level above the lake. We could find such lines if we could by surveying and leveling find all the points in the county which are exactly 10 feet above the level of the lake and join them by a line. All the country lying between the 10 and 20 foot contour lines would be between 10 and 20 feet above present lake level. The lines drawn upon our contour map are the best approximations to such lines that we can draw. But as the lake level fluctuates so much they are not referred to lake level, but to an assumed level on the Atlantic Ocean, the average level of Lake Huron being between 581 and 582 feet above the sea. The United States Geological Survey has published a dictionary of altitudes of points all over the United States, referred to this level, from which we have taken the altitudes of all points that were in Huron county.*

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*Bulletin No. 76, and third edition, No. 160, by H. Gannett.

With these as starting points, the profiles of various surveyed lines, furnished by Mr. Webber, gave a great many others. The county drains furnished the relative elevations of many more points, and finally barometric readings were taken as we went over the roads, checked up on points more accurately determined as often as possible, and the weather fluctuation as far as possible eliminated. Thus the altitudes of a great many other points were determined from those already given. At the same time the depths of stream valleys, and general character and slope of the country were noted. Finally the contour lines were drawn so as to harmonize with this accumulation of data. They have been constructed to determine primarily the relative positions of outcrops and of the strata intersected by the wells, and must be judged accordingly, but it is believed that they are not more than ten feet out, one way or the other, except in the hilly part of Verona, Bloomfield, Sheridan and Paris townships. Moreover, it must be understood that on our map we have adapted the river valleys *between section lines* to the stream as they are found on the county atlas which we have used as a base in all cases except where it is known to be wrong, so that if any stream as laid down on the map, proves to be out of position, the stream valley contours are correspondingly incorrect. With the time and means at our disposal, it was impossible to meander the streams. The expense required to produce a thoroughly accurate contour map, would be prohibitory with present Survey appropriations.

The present map cannot be depended upon for final location of railroads or drains, though it may be useful in their preliminary location. For example, it suggests that a very practicable line from Badaxe to Harbor Beach may be found by going north or northeast and then following the center line of the north tier of sections in Verona, Sigel and Sand Beach townships. But it is in the first place for geological use. It suggests, as will be hereafter shown, the gathering places for artesian water supply, and removes the mystery as to the origin of the head of water at the Badaxe flowing well. It helps us to make due allowance for the differing altitude of outcrops in estimating strike and dips, etc., and also aids us in tracing the ancient history of the lakes, and their abandoned shores. Without its help, too, the map showing the general conformation of the rock surface beneath (Pl. VII.) the drift mantle could not be constructed.

§ 5. Tables of altitudes.

(a). Lake survey bench marks. The most accurate leveling done in the county is presumably that of the Lake Survey.

The present plane of reference of the U. S. Lake Survey for their gages on Lakes Michigan and Huron is known as high water of 1838. This is 8.33 ft. below a bench mark on Dr. I. A. Lapham's house in Milwaukee, according to Plate III of Appendix SS of the Annual Report of the Chief of Engineers for 1882. This bench mark according to Professional Paper of the Corps of Engineers, U. S. A., No. 24, p. 609, is 592.67 feet above mean tide at New York (577.94 ± .36 feet above coast survey bench mark at Greenbush, N. Y.). The plane of reference of the U. S. Lake Survey which is also that of our Plate V is therefore 584.34 feet above tide (A. T.). According to the same reference the mean surface of Lakes Huron and Michigan from Jan. 1, 1860, to Dec. 31, 1875, was 11.39 feet ± 0.10 below the Lapham bench mark, i. e., 581.28 above tide. According to Crosman the mean water surface from 1860 to 1888 was 2.82 feet below the plane of reference i. e. 581.52 feet A. T. This is 0.24 foot higher than the mean level for 1860 to 1875, and most of the time from 1875 to 1888 the lake level was unusually high. A check point at Port Austin is the top of an iron bolt driven into a vertical face of bed rock on the west side of a promontory opposite the residence of Dr. J. W. Kimball, which was* 1.23 feet below the plane of reference, i. e., 583.11 A. T., and in July, 1875, and October, 1876, 7.424 feet below the Wisner bench mark, which is 6.19 feet above the plane of reference, i. e., 590.53 feet A. T., or 7.424 feet† above the check point.

(b). Altitudes from Gannett's dictionary of altitudes in the U. S. Bulletin No. 76 and 130 of the U. S. Geol. Survey. The last column is the distance as there given above tide, the second column is obtained by subtracting 582, the elevation of Lake Huron according to Gannett, while the first column gives the distance from the starting point of the railroad survey. Some stations are interpolated by profile combined with repeated barometric readings.

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*Annual report of the Chief of Engineers for 1876. HH., p. 84.
†18th Annual Report U. S. Geological Survey, Part II, p. 628.

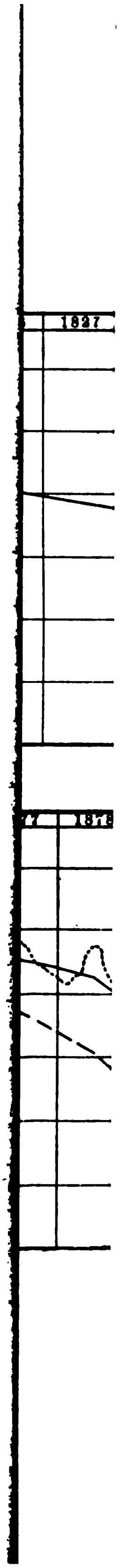

Plate V.—Illustrating the fluctuations in the level of the lakes from 1888-1899 (Sand Beach Gauge), from reports of the U. S. Engineers. From 1888-1858 from Crosman's chart, for Lake Michigan and Lake Huron, Milwaukee gauge. Previously, no special gauge. 1856-1857, Lake Survey. Previous to 1851 the data are from Whittlesey's paper. The line connecting monthly means is in dots. The line connecting annual means is full. Line connecting mean annual rainfall, for comparison, is in dashes.

PERE MARQUETTE, (PORT HURON AND NORTHWESTERN) R. R.

(*b1*) Port Austin Division.	Miles from Port Huron.	Above Lake Huron.	Above tide.
Tyre	59.9	199	781
Ubley (Ubly)	62.9	203	785
Highest Point	64.7	232	814
Wadsworth	66.4	199	781
Badaxe	70.2	169	*751
Rapson's Siding, Secs. 31, 6	73	‡162	744
Clarks, Secs. 19 30	75	‡146	728
Filion, Secs. 18 19	76	139	†721
Creevy Siding, Secs. 7 16	77	‡134	716
Kinde (Dwight), Secs. 31 6	79.6	120	701
Johnson, Secs. 18, 19	‡82	‡ 73	645
Port Austin	87	15	597

(*b2*) Harbor Beach Division.§	Miles from Port Huron.	Above lake.	Above tide.
Harbor Beach station	70.4	18	600
Lowest point of track on section 12		8	590
Shore Road crossing		16	598
Bridge over Allen Creek		44	626±6
Crossing east road between Sec. 24 and 25, T. 16 N., R. 15 E.		76	658±2
Crossing north road between Sec. 25 and 26		94	676±3
Crossing east road between Sec. 26 and 35.		121	703
Crossing north road between Sec. 34 and 35		124	706
Crossing east road between Sec. 34 and 3 *Helena*	64.7	134	716±2
Crossing east road between Sec. 4 and 9, T. 15 N., R. 15 E.		149	731
Crossing north between Sec. 8 and 9		105	747
Crossing east between Sec. 8 and 17		169	751
Five feet below top of ridge just west, *i. e.*,		174	756
Crossing east road between 20 and 29 *Ruth*	60.0	172	754
Minden City, near S. O. P., T. 14 N., R. 14 E.	56.4	235	817

*This is exactly the same union station as the Badaxe of the Saginaw, Tuscola and Huron Railroad for which Gannett gives the altitude 758 feet, agreeing with the levels obtained in the office of the Railway Company. The weather service altitude is also 758. The preliminary and final line agree and for this and for various reasons I consider the Saginaw, Tuscola and Huron levels the more trustworthy, and have made them the base of my work, but I have not changed the other levels of the Port Austin Division other than at Badaxe, because the level given for Port Austin station seems too high now. According to profile obtained from the office of the Flint and Pere Marquette Railroad, Port Austin is 33 feet, Kinde 131 feet and Wadsworth 208 feet above Lake Michigan, i. e., Lake Huron, but according to letter of Chief Engineer W. B. Sears, Oct. 10, 1896, these profiles compiled from old data are certainly wrong, Port Austin being about 14 feet above lake. The fluctuations of the lake level make this reference somewhat uncertain. I should take it to be about right for 1896 lake level, but about a foot or two too high if referred to the mean height of the lake from 1860 to 1875, which is the altitude taken by Gannett. The altitude of Badaxe is by the same profile and letter 193 feet. If we subtract 18 feet from the Port Austin elevation of the profile and from the Badaxe elevation also, it will bring the latter nearly the same as the Saginaw, Tuscola and Huron elevation, and the former also nearly correct, and the same as given by Gannett. But an equal subtraction would make Kinde 113 feet above lake or 7 feet lower and Wadsworth 10 feet lower than given by Gannett. Going south into Sanilac county a similar subtraction would leave Palms 238 feet above the lake, still higher than it is given by Gannett (812 A. T. or 213 above lake). Such discrepancies cannot be satisfactorily adjusted. We have used Gannett's figures, except for obvious misprints, e. g., Port Austin = 696, with some regard to repeated barometric measurements.

The last edition of Gannett's dictionary has lowered altitudes on the S. T. & H. and P. O. & N. seven feet. This is apparently to make the reading on Saginaw Bay of the latter line agree with the level of Lake Huron, but it seems to produce many discrepancies elsewhere and our work is based on the second edition.

†740, as given in Bulletin 130, is a misprint for 720.

‡Interpolated by repeated barometric readings, assuming Badaxe = 758.

§The town of Sand Beach has received the name of Harbor Beach quite recently. The maps were printed with the old form, but I have tried to replace the old form by the new in the text. Badaxe is also written thus by the post office authorities, but by others is often written Bad Axe.

Altitudes between Harbor Beach and Minden City have been interpolated by triple barometer readings. Bulletin No. 130 gives the altitude of Harbor Beach Station as 599, and of the cisterns of the weather service barometer as 600.

(*63*) PONTIAC, OXFORD & NORTHERN (PONTIAC, OXFORD & PORT AUSTIN) R. R.

	Miles from Port Huron.	Above lake.	Above tide.
Saginaw Bay			*588
Caseville	100	12	594
Pigeon River			588
Pigeon River (Sec. 23, Caseville)			605
Berne (misprinted Barnes)	93		627
Berne Junction, S. & T. H. R. R.			630
Pigeon River (Sec. 14, Winsor)			617
Center of Section 23	90	†62.5	
Winsor (misprinted Winson)	87	66	648
Owendale	69	69	651
Creel	73		655
Gagetown	80		754

Gannett's figures (in No. 76) agree exactly with those obtained by adding 582 feet to the altitudes of the profile, with the one exception of Bayport, for which he gives the altitude of 604 feet. We use therefore, the profile of that line, as obtained from the railroad office, more in detail. In No. 130 he has subtracted 7 feet straight through, which is a mistake.

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*The reference to Saginaw Bay is uncertain as we do not know at just what level the Bay may have been at that time. But it is not likely that the water was six feet above the 582 feet datum though if the time was the summer of '82-83 it well may have been a foot above, i. e., 583 A. T., and consequently the altitudes given below should be reduced, but when we come to the junction with the Saginaw, Tuscola and Huron railroad at Berne Junction, now called Pigeon, we find the altitude given by the Pontiac, Oxford and Northern railroad three feet below that given by the S. T. and H. (633), so that we should not be justified in subtracting from the altitude given by the P. O. and N. right along. I think, however, that the altitude of the Caseville Station is some 3 feet too high. If we should take off three feet from all the P. O. and N. altitudes and then 6 feet from all those of the S. T. & H. to make a match, the difference between the altitudes of the Badaxe station as determined from the S. T. and H. and Port Huron and Northwestern according to Gannett No. 76 would also disappear. The third edition No. 130, subtracts 6 or 7 feet from all the P. O. & N. altitudes which is probably too much. The reading on Saginaw Bay was probably when the water was at about 583 ft. Also at the junction point of Pigeon and Clifford the P. O. & N. altitudes are low when thus corrected.

†Altitude determined by preliminary survey for S. T. and H. given below.

(c) SAGINAW, TUSCOLA AND HURON RAILROAD RECENTLY LEASED BY PERE MARQUETTE.

(c. 1). Preliminary line from Sebewaing to the center of Sec. 20, T. 16 N., R. 10 E., thence by quarter line to Badaxe.

Remarks.	Station of survey.	Alt. above lake.	A. T.
Union Street, Sebewaing	1950	8	590
N. line of Sec. 8, T. 15 N., R. 9 E.	1966.58	9	591
Ridge Road	2000	14	596
West side of ditch	2022	24	606
Ridge Road	2037	29	611
	2066	28	610
Town line (168 feet E. to corner between Secs. 3 and 4, T. 15 N., R. 9 E.)	2074.35	25	607
Creek (bottom at alt. 25 ft., country 27 ft.)	2097.50	25	607
Road between Secs. 34 and 35 (270 feet to the quarterpost)	2137.39	32	614
Road between Secs. 25 and 26, T. 16 N., R. 9 E., then almost dead level	2196.81	45	617
Ditch with banks at alt. 43 feet	2250.50	40	612
Shebeon Creek (alt. of banks 42 feet.)	2269.50	40	622
Near center of Sec. 20, T. 16 N., R. 10 W.	2348	45	627
(Course thence N. 88⅓° E.)			
Line between Sections 20 and 21	2370.90	52	634
Creek, valley about 70 feet wide. (bottom of creek at an altitude of 46 feet; flood plain at 50 feet; general country level at 55 feet	2425	54	636
Offset of 239 feet N. 1° 30′ W. to quarterpost between Sections 22 and 23	2476.62	59	641
Creek	2490	60	642
Intersect P. O. and P. A. R. R. (at Sta. 526.39)	2503.78	62.5	644.5
Country level	....	60.5	642.5
Section line road (Secs. 23 and 24)	2529.85	62	644
Pigeon river and road, top of west bank	2537	61	643
Flood plain	2537.40	55	637
River bottom	2537.50	50	632
Top of east bank	....	63	645
25 feet S. to quarterpost between Sections 24 and 19, T. 16 N., R. 11 E., 2½ miles S. to Kilkenny	2582.13	68	650
	2620	70	652
Section line between 19 and 20	2631.20	72	654
21 feet N. to quarterpost between Sections 20 and 21, T. 16 N., R. 11 E.	2683.81	....	....
Angle thence N. 88° E.			
Creek in flooded woods	2696.70	70	652
Offset S. 0° 30′ E. 940 feet on Section line.			
	2719	80	662
Road, Sections 21 and 22	2736.59	....	....
	2767	90	672
	2810.50	100	682
River road, west bank of Pinnebog	2817	104	686
Flood plain	....	90	672
Bottom of river	....	84	666
East bank, front of terrace	....	100	682
Section line between 23 and 24	2838.33	108	690
Creek	2844	106	688
	2845	110	692
	2870	120	702
113 feet north to quarterpost between Sections 24 and 19, T. 16 N., R. 12 E.	2891.27	125	707
	2905	130	722
	2930	140	....
Section line between 19 and 20	2945	147	729
Road N. E. and S. W.	2975	157	739
	2985	169	742
	2990	164	746
After 2992 very flat for quite a way.			
103 feet N. to quarterpost between Secs. 21 and 22	3050.08	162.5	744.5
From here course N. 63° 27′ E.	3076.55		
Section line road, 1349 feet S. to quarterpost between Sections 22 and 23	3105.58	165	747
Change course to N. 88° 35′ E.		167	749
	3142.50	182	764
Crescent avenue, Badaxe, section line	3143.50	177	759
Road between Sec. 24 and Sec. 18, T. 16 N., R. 13 E.	3213 70	181	763

Comparing this profile with that of the Pontiac, Oxford and Northern or with that of the Saginaw, Tuscola and Huron hereafter given, it agrees very well. It does not agree with the profile of the Goodman Logging Road, if this be located as given on the town map of Oliver in the county atlas. This was a logging spur, however, and is now torn up, and is given otherwise on the map of the county.

(c. 2). The following gives the main topographic data of Goodman Logging Road:

Main track of S. T. and H. taken as beginning of Survey and at 100 feet altitude.

	Station No.	Elevation.
(Compare altitude of Goodman (=Grassmere) as given by Gannett, i. e., 686 A. T., or 104 above lake.)		
	5	97.6
	8	101.1
	40	108.1
	49	104.6
Crosses previous profile (*c. 1*) near its station 2870, i. e., about 120 feet above lake.		
	51	108.6
	76	117.4
	78	113.7
	91	123.4
	100	120.5
Bridge abutment over Pinnebog	102.70	112.9
Bottom of river		92.4
River valley, flood plain	about	93
Inner valley bench		113
Outer bench		120

It seems likely that the assumed 100 feet is about 590 feet above tide, and more than 100 feet above Lake Huron.

(c. 3) MAIN LINE OF SAGINAW, TUSCOLA AND HURON RAILROAD.

	Station number of railroad survey.	Elevation of railroad track.	Elev. of surrounding country.	Above tide.
Base about 11 feet above Lake Huron	100 ft apart			
Sebewaing	1958			593
	2330	15.00	13	607
Sand ridge road	2345	23.00		615
Bayport Junction	2354	25.50	24	617
Bayport Station	2372	30.00		622 (624)*
Bayport dock, north end	2396	13.00		605
	2413	20.00		612
	2448	40.00		632
Quarry Junction	2482	46.00	46.5	638
Rock	2488		at 46.6	
	2497		up to 50	
Leave rock	2498		51-45	
Level of ground, 54 ft.	2515.5		at 47.7 ext. up to 50	
Mud Creek	2548	45.00	42	637

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* Gannett.

(c 3) MAIN LINE OF SAGINAW, TUSCOLA AND HURON RAILROAD.—*Concluded.*

	Station number of railroad survey.	Elevation of railroad track.	Elev. of surrounding country.	Above tide.
Cut (the rest is fill) from 2,506 to 2,560	2538			
Road, east line Sec. 4, T. 16 N., R. 10 E.	2560	44.00	42	626
Pigeon River bridge, above bottom of valley,	2585	47.00		629
12 feet deep, i. e, altitude 35 ft., with river 3 feet deeper, i.e., altitude 32 feet	2583 to 2588			
P. O. & N. R. R. *Pigeon.* Compare altitude on	2640	51.50		633
P. O. & N. R. R.	2819	71	74	653
Culvert; wet marsh	2856	68	63	650
Elkton	2874	68.50	66	651
Pinnebog R., 3½ ft. above bottom	2906	70.00	66.5	652
	2940	30		612
	2970	90		672
East line Sec. 14, T. 16 N., R. 11 E.	2981	95.00	94	677
	3009		100	682
Goodman				686
	3030	111	110	693
(*Grassmere*) East line Sec. 13, T. 16 N., R. 11 E.	3033	112.90		694
Nettle Run	3068	124.50		697
	3080		120	702
East line Sec. 18, T. 16 N., R. 12 E.	3086	133.50		715
	3114		143	725
	3123		150	732
Bottom of Silver Creek	3163	156.5	151.5	739
East line Sec. 16, T. 16 N., R. 12	3193	161.25	160	743
	3230		163	745
	3244	165.00		747
About 2 ft. below railroad	3283		170	752
East line Sec. 14, T. 16 N., R. 12 E (highest)	3297	177.00	180	759
	3311.5		179	
East line Sec. 13, T. 16 N., R. 12 E.	3352.5	164.50	164.50	746
Lowest point between Sec. 14 and Bad Axe sta.	3354	164.00	162.5	746
Northwest end of curve	3370	167.00	163.5	749
South end of curve	3380.5	171.00	171	753
Badaxe yard	3390	172.00	170	754
Badaxe depot, junction with P. M. R. R.	3400	176.00	178	758

(c 4.) A compass line northerly from Sebewaing to the quarry of Sec. 5, T. 16 N., R. 10 E., gives some additional data important as to the lower lake ridges.

	Station of railroad survey.		
Main line near Sebewaing	1,966	8+	582=590
Ridge road	2,000	14	596
Ditch, bank 20 ft. on one side and 24 ft. on the other			
Mound sloping down to 23 ft. on the other side; bottom	2,022	18	600
Ridge road; west side of ridge 20 ft., east side 24 to 25 ft; top	2,037	29	611
Country level is 27 feet above base at summit			609
Town line road	2,070.35	25	607
Creek		25	607
Line between Secs. 34 and 35, T. 16 N., R. 9 E.	2,137.39	32	614
Line between Secs. 25 and 26	2,197	42	624
Surrounding country of Shebeon river		43	625
Shebeon river	2,270	40	622
Angle to due north on Sec. 20, T. 16 N., R. 10 E.			
South line of Sec. 5	2,490	44	626
Highest point on compass line		49	631
Town line road (north line of Sec. 5)	2,541	42	624
	2,574	37	619

(c 5). A survey from Sebewaing to Kilmanagh and thence to Caseville gives probably (the datum is uncertain).

	Station No.	Elevation above lake.	Elevation above tide.
	2000	11	593
	2010	21	603
Line between Secs. 3 and 4, T. 15 N., R. 9 E......	2030.50	20	602
	2046	17	599
Creek (banks at 23 feet)........	....	21	603
Line between Sec. 2 and 3........	2085	30	612
Line between Secs. 2 and 35, T. 16 N., R. 9 E......	2116	35	617
	2107.25	38	620
Line between Secs. 35 and 36, T. 16 N. R. 9 E.....	....	40	622
Line between Sec. 36 and Sec. 31, T. 16 N., R. 10 E	2196.50	40	622
Line between Secs. 29 and 30........	2304	50	632
Line between Secs. 28 and 29........	2305	....	....
Line between Secs. 21 and 28........	2360	45	627
Line between Secs. 16 and 21........	2414	45	627
Line between Secs. 16 and 9........	2468	44	626
Line between Secs. 9 and 4........	2522	42	624
Line between Secs. 4 and 3........	2523	41	623
Thence all the way a beaver swamp to line	....	34	616
between Sec. 3 and Sec. 34, T. 17 N., R. 10 E........	2776	33	615
Line between Secs. 27 and 34, and between Secs. 27 and 22, T. 17 N., R. 10 E........	....	34	616
From 2705.50 to 2735 altitude the same........	2735	....	....
Line between Secs. 15 and 22........	....	32	614
Line between Secs. 11 and 14........	2790	25	607
Watery all the way from........	2798	23	605
to........	2848	22	604
Course changes at........	2912.47	23	605
Creek (banks at 17 and 19 ft)........	2923.70	14	596
Line between Secs. 2 and 35, T. 18 N., R. 10 E....	2900	20	602
Road (center line of Sec. 35) runn'ng east........	2927.50	18	600
Caseville........	2940	20	602

The altitudes above agree very well with those of the Saginaw, Tuscola and Huron R. R., where this line crosses the latter on Sec. 4, T. 16 N., R. 10 E., but are a little lower than that of profile (c 1) where this line crosses that on Sec. 21, and seem rather low near Caseville, but nearly right.

(d). Miscellaneous data from Mr. W. L. Webber.

The east part of Sec. 5, T. 16 N., R. 10 E. has been contoured and at the center of the northeast quarter the altitude is 56.4 feet (638.4 feet A. T.) the altitude of Mud Creek on the north line of Sec. 4 is 37.4 feet (= 618.9 feet A. T.), on S. line, 41.8 feet (= 623.3 feet A. T.). Farther altitudes will be found in connection with coal explorations in Secs. 17 and 18, T. 15 N., R. 9 E., and in Sec. 5, T. 16 N., R. 10 E., Secs 35 and 36, T. 17 N., R. 9 E.

(e). Abstract of cross-section leveled with wye level at Port Austin, on August 6, 1886, by A. C. Lane and C. A. Davis, south on center line of sections 30 and 31, Port Austin Township, T. 19 N., R. 13 E.

From water's edge.	Chains.	Alt. above lake.	Above tide.
Water level that day	0.00	0.00	578
Top of old beach crest	......	4.03	582?
Level of Spring street, and usual datum for our barometric work, assumed as 592 feet above tide, *i. e.*, 10 feet above lake datum, but very probably nearer 12 feet	3	13.91	592
	4	14.75	......
	5	13.64	......
	6	14.00	......
	7	20.97	598
First dune line or ridge (height of instrument when on this bench, 30.80)	8	25.25	603
Hollow back of first ridge	9	23.21	601
Level of dunes to east and west	......	35.42	612
	10	27.07	......
	11	31.10	609
Bench back of dunes, water line at level of Lake Algonquin	12	25.98	604
Front of back bench	13	24.18	602
End of sand	14	20.43	598
Washington street	15	......	......
Bottom of flat swampy plain	19	14.16	......
The instrument is about on level of the Broken Rocks bench at a height of	......	36.72	615
	......	30	......
	24	23.26	......
	......	27.37	......
At 39.49 a fence	39	42.02	......
Bench mark on beech tree at 47.28	......	......	......
No higher land east or west	45	54.25	......
Crest of little beach-ridge, shingle	46	57.27	635
Hollow back of same	47	56.63	635
Slabs of rock at 54.50 chains	50	60.03	......
Instrument on a beach line at an altitude of	......	69.15	647
All along here woodchucks throw up slightly fossiliferous flagstones	56	68.17	......
	57	......	......
	60	73.36	......
	68	80 32	......
	70	80.83	......
Sandstone outcrops on hill west	......	91.97	670
Height of instrument on top of hill is 99.71, *i. e.*, top of hill is about	......	94	......

Another line of levels referred to below was run by Locke level near Bayport up to 40 feet, and gave practically the same altitudes for terraces, etc.

(f). Altitudes obtained by barometer.

The altitudes of the points given below were obtained by barometer in the course of our bicycling trips, but are picked stations which have been occupied at least twice, with harmonious results after allowing for the weather variation. The altitude is not supposed to be more than five feet out, one way or the other, supposing that the nearest railroad levels are correct.

	Above lake.	Above tide.
T. 19 N., R. 13 E., Port Austin, N. E. cor. Sec. 27	60	642
T. 18 N., R. 14 E., Huron, bridge over Willow creek, S. line of Sec. 8	33	615
N. W. cor. Sec. 31	116	698
N. quarter-post Sec. 33	99	681
T. 18 N., R. 13 E., Dwight, N. W. cor. Sec. 36	119	701
N. W. cor. Sec. 21	71	653
N. W. cor. Sec. 31	108	690
T. 18 N., R. 12 E., Hume, E. quarter-post Sec. 12	57	639
S. E. cor. Sec. 13	75	657
N. E. cor. Sec. 31	37	619
S. E. cor. Sec. 34	85	667
T. 18 N., R. 11 E., Lake, N. W. cor. Sec. 36	46	628
T. 17 N., R. 15 E., Rubicon, S. E. cor. Sec. 33	96	678
T. 17 N., R. 14 E., Bloomfield, N. quarter-post of Sec. 9, (Redman)	131	713
State road on N. line Sec. 20	130	712
S. W. cor. Sec. 31, Rapson	160	742
T. 17 N., R. 13 E., Lincoln, N. W. cor. Sec. 7	126	708
N. W. cor. Sec. 18	133	715
N. W. cor. Sec. 30	143	725
N. W. cor. Sec. 31	163	745
S. E. cor. Sec. 31	166	748
T. 17 N., R. 12 E., Meade, S. E. cor. Sec. 6	68	650
S. W. cor. Sec. 36	146	728
T. 16 N., R. 14 E., Sigel, N. W. cor. Sec. 18	192	774
Verona Mills, W. quarter-post Sec. 19	238	820
T. 16 N., R. 13 E., Verona, E. quarter-post Sec. 10	168	750
N. W. cor. Sec. 7	166	748
N. W. cor. Sec. 18	188	770
Summit of hill on N. E. ¼ Sec. 23	273	855
Bridge over Willow creek, Sec. 23	182	764
W. quarter-post Sec. 22	200	782
W. quarter-post Sec. 21	185	767
S. W. cor. Sec. 35	234	816
S. W. cor. Sec. 31	177	759
T. 16 N., R. 12 E., Colfax, S. E. cor. Sec. 6	111	693
T. 16 N., R. 11 E., Oliver, S. W. cor. Sec. 1	82	664
S. W. cor. Sec. 35	141	723
T. 15 N., R. 16 E., White Rock, S. W. cor. Sec. 7	72	654
T. 15 N., R. 15 E., Sherman, crest of ridge east side of Sec. 7	174	756
S. E. cor. Sec. 35	98	680
T. 15 N., R. 14, E., Paris, S. W. cor. Sec. 3	195	777
S. W. cor Sec. 18	222	874
S. W. cor. Sec. 19	216	808
S. W. cor. Sec. 18	196	778
T. 15 N., R. 13 E., Bingham, S. W. cor. Sec. 19	225	807
S. W. cor. Sec. 31	254	836
T. 15 N., R. 11 E., Grant, S. W. cor. Sec. 7	80	662
S. W. cor. Sec. 15	125	707
T. 15 N., R. 10 E., Sebewaing, Voltz creek bottom, on E. side of Sec. 14	48	630
N. side of Sec. 14	41	623

§ 6. The hill district.

Glancing upon the contour map previously described it will be apparent that Huron county may be divided into two districts, the hill district and the plain district. The latter may be subdivided into still smaller districts, but the former makes a well defined core or back bone to the county. It occupies, as is apparent from the map, a roughly triangular area extending from the north part of Verona township south-southeast to Parisville and west-southwest to Gagetown. In it head all the important streams of the county. It is higher to the east than to the west and while the valleys range from 165 to 213 feet above lake or 745 to 795 feet above tide, the hills rise frequently to some 850 feet above tide (occasionally some thirty feet more), or up to 100 feet above the valleys. It is characteristic that it is not flat like the surrounding plain, whose smooth slope indicated by continuous contours is only broken by stream valleys, but that it has hills of gravelly clay or till, whose contours may have been cut into by running water, but are not principally determined by it. The streams which flow between them often flow in valleys which are ridiculously large for the present size of the streams. This is particularly true of Cass river and Willow Creek. Sometimes* undrained hollows will be found on the top of the hills with pools of water standing in them in the wetter part of the year.

Frequently these hills are terraced on their sides with sand and gravel, and especially as we go toward the margin of the district the clay ridges become lower and lower and are gradually buried under a mantle of gravel and sand which marks the boundary of this region. These till ridges, as may be seen at a glance at the map (Plate VIII), are the chief watersheds in this region. In several places the main ridges border upon swamps which are long and narrow like river valleys. In other cases the ridges may actually enclose quite considerable marshes without any outlet. Such a case is seen on Sec. 18, Sheridan, T. 15 N., R. 12 E., and these sand plain gravels or ridges are also well developed on Sec. 30 and elsewhere in the same township, where gravel also occurs in the form of eskers. Beside the hills of gravelly clay and these gravel deposits, this region contains also considerable swamp land. The streams have not had time to cut proper drainage channels, but it is all easily drained, and such old swamps, with a soil composed of muck underlain by shell marl are most fertile land. The shell marl points to a time when these swamps were lakes, and one such lake is left in this district—Mud Lake—on Sec. 32, Grant, T. 15 N., R. 11 E. Apparently it would not be difficult to drain this off into the Shebeon or into the Pigeon. Probably the shortest way of draining the whole lake would be into the former. This district is particularly ill adapted for the system of rectangular roads which obtains, as it involves a great deal of unnecessary up and down hill. It is easy to see valleys on the map which would make easy grades between the important points. The kames and askers furnish excellent road material, in their gravels, and are very porous so that they dry easily.

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*e. g. on top of a hill on Sec. 34, Verona, T. 16 N., R. 13 E.

§ 7. The plain district.

Around the rolling nucleus of low hills just described sweeps a great plain, which includes most of the county. While to the eye it often appears perfectly level, except for the stream valleys carved in it, in reality it falls gently but steadily with no prominent exceptions, in all directions away toward the lake, until it is about 20 feet above it on the west side and about 40 on the east side. The stream valleys are usually not over 20 to 30 feet deep, growing deeper toward the margin of the plain, and not over 500 feet wide, and have steep sides showing their youth. It is a typical coastal plain.

The soil is usually a calcareous gravelly clay, diversified with low ridges of sand and gravel, or bouldery streaks which run in a general way parallel to the contour lines. To one standing on a prominent hill near Verona, and looking east the contrast of the two districts is as plain as in the diagram in Frye's Physical Geography, p. 12.

In this plain the streams have not developed marked ox bows and the only thing that can be called lake is a small body of water on the south side of Sec. 11, Chandler, T. 17 N., R. 11 E., which will doubtless soon be drained into the Pinnebog or otherwise. As the streams cut through these surface sands, which usually also line the borders of their valleys as a continuous fringe of delta deposit, down to the underlying clay, springs are likely to appear along the point of contact of overlying sands and clay. Excellent examples of this action may be seen on the road along the west line of White Rock township, T. 15 N., R. 16 E.

Along the upper part of this district some stimulus to the stream drainage is required, and so we find from Brookfield around through Lincoln to Paris, a strip of country which is artificially drained. As we get toward the margin of this district the trenches cut by the streams deepen. The Pinnebog and Pigeon have both cut down about as far as possible and are now vigorously at work lowering their grade by lengthening their course by enlarging their curves, swinging from bank to bank of the flood plain and cutting away at the bluffs which border it. Corpare Sec. 26, Chandler Tp. and Sec. 25 Winsor. On the east side of this district, the streams flow, "in their narrow U-shaped trenches, quite regularly down the slope direct toward the lake." There are an extraordinary number of nearly parallel streams. This is also true on the west side for the upper part of the slope, but then the streams are all deflected to the north. This deflection is probably in part due to the tendency already noticed for the sand to work back against the shore and along to the northeast on this side of the county (§ 3) so that there was a tendency to deflect the streams with the sand that they themselves bear down and turn their mouths northward. When, for example, the mouth of the Pinnebog was near Elkton the sand brought down by it and by its neighbor the Pigeon and by other streams immediately south, was deposited abundantly where we now find it on Secs. 16 and 17, Oliver, and may have assisted in turning its course northward. There are, however, faint irregularities of the old plain, undulations in the ground moraine, as it is called, which have also assisted in this action.

Some of the exceptions to the general slope of the plain deserve notice. There are a number due to the outcrop of the Marshall sandstone. Section 31, Port Austin, and Secs. 3 and 13, Dwight, Secs. 6 and 15 Meade, and perhaps also the southeast part of Lake show low rises due to this cause. Certainly in the southeast part of Huron and Bloomfield townships the eastern border of the Willow valley is marked by the buried sandstone escarpment. The limestones of the Bayport quarries are also marked by a ridge. In the northwest part of Rubicon township a number of streams seem to have been grouped together behind the heavy gravel ridges between 128 and 108 feet above the lake. Finally through the central part of Chandler and the northwest part of Oliver is a low ridge of the ground moraine.

§ 8. The eastern shore.

Sometimes, as just north of White Rock, we find the plain descending until it drops off to the lake in a single bluff, but more often we find a narrow zone with a stairlike structure, a sea cliff and a bench, then another cliff and another bench. The top of the first cliff is from 30 odd to nearly 100 feet above the lake (Sec. 3, Huron township)—but its bottom is pretty uniformly about 25 feet above. The bench slopes from this level pretty gradually, though with lesser breaks down to about 17 feet above the lake. Often there is a sheer cliff from this level down, but at times there is another bench 10 feet above lake (592 feet A. T.). The risers of this flight of stairs are often too steep for cultivation, and often stony. The benches also are often stony, especially toward Point aux Barques, but were originally marshy. "The upper terrace follows the shore line closely nearly all the way. About three-fourths of a mile north of White Rock the lake has cut away the intervening space and is now undermining and cutting back the bluff, which is here about 40 feet high, composed entirely of clay. The section shows about 35 feet of typical till,—blue clay, filled with pebbles and cobble stones; above this three to five feet of yellowish clay stratified, includes some sands; above this about one foot of soil." This upper terrace is cut by numerous short streams "which set back but a little into the uplands, and cut steep narrow channels in the edge of the plateau. The principal shore road runs generally just above or at the foot of the upper bench."*

§ 9. The western shore.

This district is much more important than the eastern, but has about the same limits of altitude. Beginning at the north extremity of the county around Point aux Barques, there is a practically continuous ridge of knobs of shifting dune sand, which continues, swinging from point to point, like draped festoons, clear to the southwest edge of the county. Exceptionally high knobs rise more than 40 feet above lake (620 feet A. T.), but in general the top of the ridge is a little above 30 feet above lake level. The ridge road crossed by the railroad lines, § 5, (b, 1) and (b, 3), at 29 feet is on the lower part of this ridge. On the landward side this ridge is backed by extensive swamps, now rapidly being artificially drained, at an altitude of 20 to 24 feet above lake (606 feet A. T.). On the lake side we find a series of sand and gravel beach ridges, interspersed with swamps. Their altitudes are quite various, depending somewhat upon how far the ridges pass into dune sand aggregates. There are in places at least four or five distinct strand lines. Occasionally, as around Sebewaing, on very gentle slopes the sand ridges are spread so far apart that the normal soil of gravelly clay appears between them, but in general the soil of this district is too sandy to be good, except in the swamps, and the roads are very heavy in dry weather, and best mended by clayey material such as the burnt waste from the coal mines. A characteristic feature of this district is the number of ponds. These are of the lagoon type, i. e., originally portions of the lake shut off by barrier beaches. Such was Bear Lake, near Port Austin (now drained, by cutting through the barrier beach) on the south line of Sec. 25. Back of Hat Point was one, and a filled up cranberry bog indicates another. Rush Lake is the largest of this type. Around Oak Point are about three more. Around Sand Point some seven more, while beds of calcareous marl under some of the swamps point to the former existence of others. Probably before this report is printed some of those enumerated will also be converted into marshes by nature, or into fertile meadows by man. On Charity Island was one of these ponds which had temporarily disappeared, when I visited it, leaving a bare expanse of cracked and treacherous mud. Were Lake Huron to remain at its present low level a few seasons more a growth of vegetation would cover the pond permanently. In all we may reckon some sixteen of these "lagoon" ponds at least, in altitudes ranging from 22 feet above the lake (604 feet A. T.) down—quite a contrast to the practically pondless condition of the other districts described.

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*Quotations are from notes of C. H. Gordon.

The origin of these ponds were very beautifully shown in revisiting Oak Point in 1897, and the effect of the oscillations of lake level on a growing shore. The fall of water level culminating in 1895 had added a broad smooth slope some 400 feet wide to the shore of the southwest side of Oak Point. The recent rise had not gained on this smoothly, but had rolled up a ridge ahead of it, two feet high or so, behind which shallow ponds were formed, and the indications were that the lake would never regain what it had lost, but that a new ridge at about equal height would be added to the shore and would be separated from the old shore ridge by a swamp and by shallow ponds quickly converted to swamp. The whole space back of Oak Point to the road is filled with alternations of ridge and swamp to be explained this way, though mainly referrible to the higher 20-25 foot level. These ponds are a great resort for wild fowl. The soundings of the Lake Survey show that if Lake Huron were to drop 12 to 18 feet, several more similar ponds would be formed.

In this district the principal streams, the Pinnebog, the Pigeon and Sebewaing wind round in oxbows characteristic of streams which have had much time for lateral erosion and the stronger streams of the eastern side had time while the lake stood at the 25 foot level to cut their main valley down to this level and are also winding in oxbows, for instance the Allen on Sec. 24, Sand Beach Tp.

South of Sebewaing and for a short distance on the road from Port Austin to Port Crescent, the dune line is interrupted and the shore type is rather that of a cut terrace like that on the eastern shore.

CHAPTER IV.

FORMATION OF THE SOILS AND SUBSOILS (PLEISTOCENE).

§ 1. The preglacial surface.

The materials of which the earth's crust is composed are in Huron county so sharply divided into consolidated and unconsolidated shale, sandstone or limestone rock, on the one side, and soils and subsoils, i. e., gravels, sands, hardpan and the like on the other, and the physical geography just described is so dependent upon the latter that it seems wise to invert the historical order and describe the latter first. During the interval btween the formation of the latest rocks represented, and the earliest of the unconsolidated deposits of the Pleistocene, a long time elapsed. Geological periods passed away, and the surface of the rocks, after having been buried beneath we know not what other sediments, was for a long time a land surface. By subtracting the depths to rock in different wells from their altitudes as obtained on Plate VIII, we are able to get a number of altitudes of the rock surface, and thus draw a contour map of that surface, which is naturally much more hypothetical than the map of the present surface. This is illustrated by Plate VII. Though the present hill district is supported upon an elevated sandstone platform of underlying rock, we notice some other features of the rock surface which are not at all indicated by the present topography. One such completely disguised feature is the old river valley which runs through the township of Winsor and the southwest part of Sebewaing. While the exact location of the river valley is somewhat uncertain, its general course is not and is quite in accord with numerous other river valleys of similar nature known elsewhere in Michigan, and indicated by sudden irregularities in the drift.*

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*In Hillsdale county, H. P. Parmelee, has noted such a river valley and described it in a paper read before the American Association and from the records sent us by well-drillers another passes close to Jonesville in the same county. Farther indications of such valleys are found near Alma, Midland, Saginaw, Unionville and elsewhere.

§ 2. The ice age. (Glacial epoch.)

We can see from these valleys that at one time the base level of erosion, i. e., the water level down toward which the streams were cutting, was much lower than the present lake surface. Such buried river channels taken together with others outside the county, raise in the mind the strong presumption that the land at one time stood higher than at present. This higher elevation may have had some influence, as well as a number of other causes which have been suggested, in bringing on the accumulation of ice that followed. Even in the tropics high mountains are now covered with perpetual snow, and as we pass north to the temperate regions this perpetual snow line lowers. If now a large portion of a country is raised up to this level of perpetual snow and the precipitation is greater than that gradual wasting which takes place even in the coolest, dry winter days, we have the conditions necessary for producing a vast ice sheet, for, once such a state of things is established, the white surface of the snow tends to reflect the arrows of the sun's heat like a polished buckler, and thus perpetuate its own existence. In other words, perpetual snow once established will tend to accumulate, and slowly compacting into ice will creep like a vast flood of stiff treacle far beyond the original area, just as it now does in Alaska, Switzerland and Greenland, until it meets a climate mild enough to melt it away as fast as it advances. Now, we find that over the surface of Huron county there advanced such a sheet of ice from the north, filling up and evening off the valleys with a mass of miscellaneous material derived from farther north, and dragged along or carried with the ice. The rocks and sand in the base of this moving sheet of ice scratched, or polished and grooved the underlying rocks (Pl. IX). Evidence concerning the motion of the ice is derived from two sources: (1) the direction of the striæ,—N. 10° W. at the Bayport quarries (observations around Port Austin are not so trustworthy as they may be due to shore ice). (2) Character of transported material. The boulders on the surface, e. g., the chiastolite schist on North Island, and the material of beach sands and gravel are not to be implicitly trusted, since they may have been transported by floe ice (Chapter III, § 3), when the lake was at a higher stage. For example, in the collection of Mr. Webber, there is a small piece of native copper, which is said to have been obtained from the stripping of the Bayport limestone quarry, and most likely was thus transported. But the boulders of the till and the high level gravels, the overwash of the moraines and kames, and the very first lake beaches formed at the immediate margin of the ice are more valuable.

Important observations are:

Sec. 23, Verona. Altitude 857, A. T. hornblendic rocks, quartzites, granites pink and white, also white chert apparently from the Corniferous or Upper Helderberg, black calcareous shales, with trilobites apparently *Phacops bufo* of the Traverse, reddish-green sandstone, like the grindstone, etc.

Sec. 35, Caseville, *Atrypa reticularis* in blue shale;

Sec. 4, Winsor, and Sec. 26, Caseville, gypsum in drift. According to Davis on northernmost ridge are granite, volcanic and trap rocks, pyritiferous quartz, also found near Badaxe and now in Post and Seeley's bank; jasper conglomerate quite frequent.

This sheet of ice extended, as we know from the reports of adjacent States, down to the Ohio River, carrying with it fragments from the Laurentian highlands of Canada, whence it is called the Laurentide glacier.* Fragments of Canadian rock are frequent in Huron county, and the Corniferous cherts and Hamilton rocks which outcrop north of the county, beneath Lake Huron as well as in Canada. Such a glacial ice sheet would naturally be very much affected by the weather, the front being wasted away, or retiring during a series of dry seasons, or hot seasons, just as present glaciers are found to be advancing and receding. In this respect it would be like the lakes whose fluctuations extending over a series of years we have already described. Such fluctuations have been noted extending over many miles by geologists who have followed along the margin of the glacier. One evidence of such recession and re-advance is found in forest beds, i. e. indications of soil and wood, between two beds of gravelly clay or till, laid down beneath an ice sheet. Huron county is, however, far back from the ice front and we have no clear indications that such a retreat of the ice occurred until after the last period of farthest advance, which has been called the Wisconsin advance or stage.†

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*Maps of the extent of this glacier are very numerous. One of the more recent is by Leverett and Taylor in the Inland Educator, August, 1896, p. 29, American Geologist, Vol. XXIV, Plate II.

†Leverett Inland Educator, loc. cit.

In a few well records as in Secs. 11. 17. 18. 30. Sebewaing. beds of sand or gravel are reported under hardpan. i. e.. till or gravelly clay. but in many cases these are just above the rock and may have antedated the first advance of the ice sheet. In Sec 3. Brookfield. chips were brought up at 130 feet and in boring some other wells chips have been found. This is again near the bottom. and may have antedated the glacial period. as it is in a well in an old valley, where the soil and trees before the ice would be especially likely to be overriden. A piece of wood was taken from the pump of the Badaxe waterworks. but all the experts to whom I have shown it unanimously agreed that it must have found its way there accidentally.

§ 3. The ice retreat. (Early Champlain or terrace epoch.)

The ice period is then. as regards Huron county so far as we know practically a unit. and we cannot here learn how long the ice rested upon the county nor what was happening in the meantime. History is a record of current events. and there can be no history when nothing happened. while the county slept beneath the white sheet of ice. History begins again when the ice retired from the county. But to make the story clear we must begin before the retiring ice front had reached Huron county. For our knowledge of the course of events at this time we are much indebted to Mr. F. B. Taylor,[*] from whom we thankfully borrow a plate of the thumb region to illustrate the course of events of this epoch.—the Champlain or Terrace epoch.—Plate VI.

As the sheet advanced, it followed the low grounds like a river and as it melted back it lingered in the valleys longest. One lobe of the ice went down Saginaw Bay and another down Lake Huron. and they met in a thinner sheet over the sandstone ridge which projects into Huron county. Lakes formed in front of the melting ice and drained off to the Mississippi. In front of the Saginaw lobe a lake formed, called by Taylor, Lake Saginaw, which passed over the watershed between Ashley and Bannister, and flowed down the Grand River to a larger lake, which lay in front of another lobe, covered somewhat more than the southern part of Lake Michigan, and near Chicago drained off to the Mississippi.*

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[*] A very clear and popular resumé is "A short History of the Great Lakes," No. X of the Studies in Indiana Geography. issued by the Inland Publishing Company, Terre Haute. Indiana. May. 1897. well illustrated. and especially to be recommended to teachers. See also article in American Geologist. Vol. XXIV. July. 1899. This report we in general follow. A technical paper. with references to the earlier literature. is in Vol. 8. of the Bull. of the Geol. Soc. of America. Jan. 1896, pp. 31-58. This paper contains the plate of the thumb region. which we reproduce in Plate VI. Numerous earlier papers of Taylor. Leverett. Upham. Tarr. Gilbert. Spencer and others will be found scattered through the American Geologist, Bulletin of the Geological Society. and Am. Jour. of Science. Particular attention may be called to Spencer's popular paper in Appleton's Popular Science Monthly. June. 1896. "How the Great Lakes were Built." It will be noticed that his views do not agree with Taylor's. but the views of the latter were based particularly upon studies in Huron county and neighborhood. and I consider them decidedly more nearly correct in reference to this region. For a fuller description of the earlier stages of the ice retreat see also Sherzer's report on Monroe county. Part I of this volume.

Some old shore lines of this old lake are indicated on Plate VI. Gradually the ice retreated, and Lake Saginaw grew toward the northeast, and the streams began to work their way down to it from east, south and west.

But before this, another lake had formed in front of the Erie Huron lobe of the ice front, called by Taylor, Lake Maumee, which drained off past the town of Fort Wayne, down the Wabash. As the ice front retreated it was only a question of time when these two lakes would mingle, and it is easy to foresee that their meeting point would be in Huron county or just south of it. But the level of these two lakes was not the same. As we find their water marks at the southwest and southeast ends of the hill district respectively (Plate VIII), Lake Saginaw was some 75 feet below the highest watermark on the other side.†

As Lake Whittlesey and Lake Saginaw were independent the beaches of the one cannnot be closely parallel with those of the other,—at least it is not to be presumed without proof that the permanent water stages of the one were correspondent to those of the other. In a general way, however, the two lakes were coeval. Taylor gives for altitude of the Forest Beach at Gagetown 765 feet, but I think that the gravels he probably had in mind were deposited before free water communication was established around the point. The beaches around the outlet of Lake Saginaw Taylor gives as 750 or 746 above tide or 100 feet above the channel floor at Pewamo. The highest point of the channel floor of the outlet must be, by levels of the Ann Arbor line which is about 65 feet above Lake Michigan between Ashley and Bannister (according to Spencer quoted by Taylor, not over 100 feet above Lake Huron), about 647 feet above tide. Adding about 100 feet for the depth of water in the channel, will bring the altitude to that of Lake Saginaw as above given. The Lower Forest Beach is given by Taylor as only about 700 ft. above tide around Chapin and the outlet, in which case the correlation with the terraces in the Pewamo channel would not hold. But as we shall later see, there are a number of marked water levels, below the Forest Beach, especially the Grassmere Beaches, and it is possible that Taylor has lost track and jumped over to the Grassmere Beaches in going between Gagetown and Chapin, as he could not follow the beach continuously. The high beaches of the Pewamo channel may correspond with some stage of Lake Saginaw during which the ice had not melted back as far as to Huron county. This subject will be considered later.

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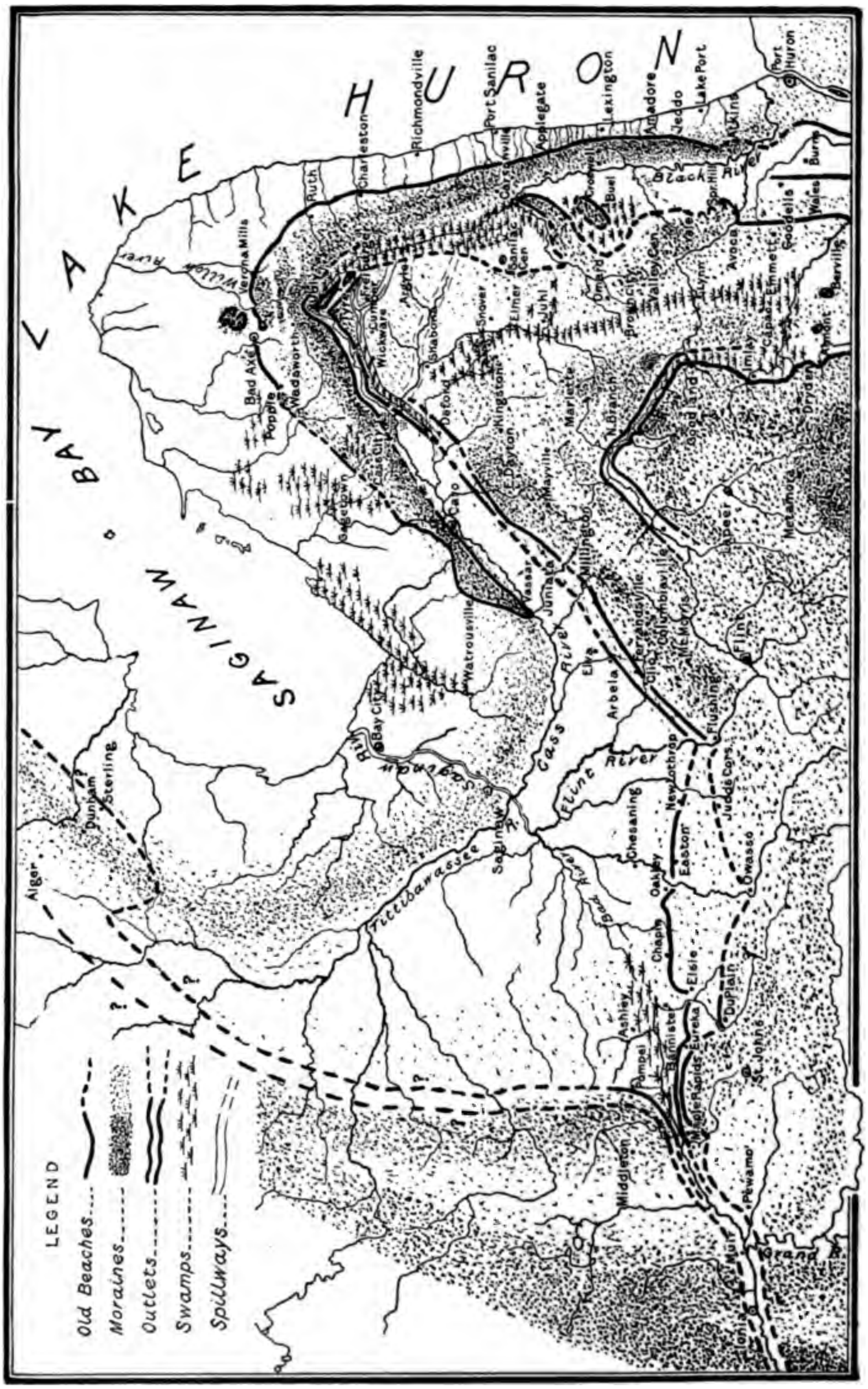
*Leverett, Bull. No. II, Geol. and Nat. Hist. Survey, Chicago Academy of Sciences.

†Note the change of topography at the 820 foot, respectively 740 feet contour lines, more particular observations are: Cass City, Tuscola County, on broad terrace (probably stream delta), 742 to 748 feet A. T.; west line, Sec. 29, T. 15 N., R. 11 E., Grant, highest gravel deposits, 744 feet A. T., same section, centerline, top of gravel bench, 740 feet A. T.; same section, 500 paces E., 1,500 paces N., 747 feet A. T., also gravel bench on south line of Sec. 21, 750 A. T.; on west line of Sec. 31, 727 feet A. T. On the other side of the hill district the beach line is by no means so well marked, but compare in Paris Township: Sec. 18, north line, front of gravel bench, 809 feet A. T.; Sec. 20, north line, top of gravel bench, 819 feet A. T.; Sec. 31, sandspur from east. 827 feet, A. T.; Sec. 34, north line, river channel, swamp, 811 feet A. T.; Sec. 34, in Bingham township (see below), sand spit, 809 feet, A. T. Average for Lake Saginaw about the time it reached Huron County, 744 feet A. T. According to Taylor, by the evidence of the Duplain beach it was at one time 20 feet or more higher.

Probable altitude for Lake Whittlesey (large successor of Lake Maumee). 809 ft.

On the east side of the Hill district, Taylor saw no signs of lake level above 775 feet above tide, but he will remember that the character of the topography changes at some distance above the Forest beaches, later to be described. It is probable that the ice retreated rapidly from the heavy moraine which has its apex in the northeast corner of Bingham, that the water extended on the east side only for a short time as a long narrow sound in front of and between the ice and its recently deserted moraine, so that there was no pronounced beach line, and the gravels would be hard to distinguish from overwash gravels. I frankly confess myself unable always to discriminate between the two. On Sec. 34, Bingham, i. e., on the old channel connecting the two lakes, there is a hill (267 feet above lake) 849 feet above tide on which is a well marked spit 809 feet above tide. This is quite certain. According to Taylor the earlier stage of Lake Maumee was about 795 feet above tide, while the later Lake Whittlesey, at the time when it reached nearly to Huron county was 800 feet plus on the Tyre Ubly outlet, while other beaches were found at 817 feet near Berville, 825 feet near Almont, 849 feet near Imlay (p. 36). Taylor leaves the question of the exact correlation of these beaches open, and owing to the fact that the beach lines of these old lakes cannot be supposed exactly even, and that the Port Huron and Northwestern R. R. levels are, as above mentioned (Chapter II, § 5), not as accurate as could be wished, it will probably be some time before the exact correla-



ERIE-HURON BEACHES IN SOUTHEASTERN MICHIGAN AND THEIR RELATED OUTLETS AND MORAINES, BULL. GEOL. SOC. AM., VOL. 8, PL. 2.

tion of these beaches can be established with any certainty. Taking the observations on Sec. 34, Bingham, in connection with that on Sec. 31, Paris, and those further south quoted by Taylor, there seems but little doubt that while the water level on the eastern side was still considerably above 800 feet, the ice front had melted back to the southern verge of Huron county. Then we may suppose Taylor's Arkona Beach to be a faint subsequent stage, probably marking a time when the channels across the point south of Verona Mills had lowered the waters of the lake on the east, Lake Whittlesey, so much that their own capacity for discharge was cut down and a state of equilibrium was temporarily established. The level of the lower lake, Lake Saginaw during all this time, like that of most lakes with large inflowing and outflowing stream, would fluctuate according to the climate from month to month and from year to year, without much changing its general level. Hence there would be a tendency for the waters to find their way across the "Thumb" from the waters on the east to those on the west. That was exactly what happened. The waters found their way along the valley now occupied by Black River in Sanilac county (see Plate VI) and across the divide by various shifting channels in Sanilac county, described by Taylor, and more fully noticed in Gordon's report on Sanilac county,* which we need not therefore mention further. They are shown in part on Plate VI. The first channel that particularly interests us is one of the strongest and most permanent of all and just enters Huron county. The rush of waters came up past Palms and Tyre, scouring away the surface "till" down to the sandstone floor, up through sections 34 and 35, Bingham, cutting a bench on the sharp hill on section 34 on the west side of the channel, and drawing it out in a long spit with an altitude of about 809 feet. The water level of the lakes at those times undoubtedly varied from year to year, and from month to month as it does now, probably in even more marked degree, as the cold of winter would have even more effect in checking the flow of water from the ice sheet. But we may safely take the average stage of water in the river between the two lakes at this point as somewhere about 810 feet. But since the stream had had to flow 30 miles or more up north, following the Black River valley, the level of the lake corresponding to this outlet, may have been a couple of feet higher, if the grade was the same as that of the present Saint Clair River. The waters thus running north probably met on Sec. 22 a large stream issuing from the melting ice sheet at the angle between the Saginaw and the Huron lobes, and were deflected south so as to follow along the margin of the Saginaw lobe down the present valley of the Cass River. Any one standing on any one of the hills overlooking this valley, will recognize at once that it is a great stream valley, vastly too large for the little Cass. In the mean time the ice front remained nearly stationary long enough to pile up on the Huron side the ridge of gravelly clay and boulders, called a terminal moraine, which runs up in Bingham township from the south part of Sec. 36, into Sec. 22; on the side of the Saginaw lobe it piled up a similar ridge from the south part of Sec. 31 into Sec. 21. These moraines do not meet, and the presumption is that the gap was in the first place occupied by the stream from the ice sheet, though at a later stage in the ice retreat a channel was found in this direction also for the waters of the eastern lake. The height of the moraine (about 844 ft. above tide) and the pronounced character of the Tyre channel, shows that this line was held for some time, but at length the ice of the Huron lobe retreated some four miles and took up a new position, extending from Sec. 33, Paris, into Sec. 2, Bingham. It does not seem as though the Saginaw lobe retreated at the same time nearly so much, as on that side the morainal ridges are piled close behind one another (Plate VIII). On the east side there are also numerous isolated rounded hills between the two main lines, which may be remnants of moraines overriden in a temporary advance.

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*Part III of this volume.

It may be that there was no general marked retreat of the ice, but that some temporary retreat was just enough to let the water work back of the moraine near Tyre, and once having opened a channel for itself through the southeast part of Paris Township it would hold it pertinaceously, even against any temporary tendency for the ice front to re-advance. To the Tyre outlet was now added a new channel well shown on the map (Plate VIII). It extends from Sec. 32, Paris, to Secs. 14 and 15, Bingham, connecting the head waters of the Cass River and the Black River.

The swamp lying in the old channel is now drained by a county drain. The swamp level is now about (213) 795 feet above tide, or somewhat higher than the Tyre channel (782 feet A. T.), and the water level was at least 801 feet A. T. and probably more.[*] It may have caused slight drop from the level when the south or Tyre channel alone was working, but it is within the range of error of our barometric observations. The water still had to find its way up by way of the Black River, and a heavy moraine ridge was built along this line,[†] rising to about 864 feet above sea level. But finally the ice front was withdrawn from this line. The ridge of till or gravelly clay strewn with boulders was[‡] more or less covered, "aproned," with gravels washed on to it from the ice, and the water either gathered in pools, like the Merjelen See of Switzerland, between the ice sheet and the moraine ridge, or worked in from Lake Whittlesey on the south. At this time the ridges marking the stages of retreat of the ice seem to have been out of water to the northwest and to have passed under water to the southeast, for these ridges seem much sharper when laid down in the air than when laid down under water, and we have for example a hill on the south line of Sec. 6, Paris, which is continued to the southeast only in a very gentle undulation. When the ice sheet, with its front thus in the water, and its flank just out of water, forming land-made ridges near the corner of Verona, Sigel, Paris and Bingham townships, retired a little farther, there was left open a channel through Sec. 6, Paris, and Sec. 1, Bingham, around to Sec. 35, Verona. This is not, however, much lower than previous outlets (780 feet A. T.), and as we find it in distinct sand and gravel deposits on Sec. 35, Verona, about 800 feet above tide (219, 216, 217 feet above lake, according to different readings), the opening of the channel could have made no material change in the lake level. It could hardly have led the water off down the Cass valley, for the lowest point on the channel on the south side of Sec. 2, Bingham, appears to be at least 805 feet above tide and I think that any discharge directly west was blocked by the Saginaw moraine and the ice. The channel on Sec. 35, above mentioned, might even have been an outlet westward of the great glacial river from the north, already mentioned, into the eastern lake, Lake Whittlesey, though we have not supposed so. Can it be shown that the current was that way?

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[*] The midchannel bar of Taylor, if it is the one on the south line of Sec. 24, is about 801 feet above tide. Compare also gravel, at 800 feet A. T. at the southeast corner of Sec. 23, Bingham. The county drain enables us to check levels along here.

[†] Of fairly uniform height, as the following observations show:
E. line of Sec. 33, Paris, 294 feet above Lake Huron.
N. line of Sec. 33, 268 feet above Lake Huron.
N. line of Sec. 28 slightly later, 295 feet above Lake Huron.
N. line of Sec. 20, 295 feet above Lake Huron.
N. line of Sec. 18, 272 ft. above Lake Huron.
E. line of Sec. 12, Bingham, 274 feet above Lake Huron.
N. line of Sec. 12, 280 feet above Lake Huron.
E. line of Sec. 2, 280 feet above Lake Huron.

[‡] So on the north line of Sec. 18, Paris.

Even the retreat of the Huron lobe of the glacier two miles farther north, so that its flank emerged from the water near Verona Mills on Sec. 24, Verona, seems to have left the ice front at first at much the same level, for near the southwest corner of Sec. 25, Verona, there are extensive sand deposits and gravel ridges at an altitude of about 801 feet above tide, and a gravel ridge or spit near the center of Sec. 24 at a corresponding elevation. The bottom of a channel in Sec. 24, which is followed by a county drain is at much the same elevation as previous channels (789 feet A. T.). I think I can trace signs of a water level in a faint terrace along the valley of the Willow, a discontinuous bench visible in a series of spurs from the ridge east, which thus gives us some idea of the size of the glacial stream from the north at this time, filling a valley about half a mile wide, to a depth of perhaps (218—182) 36 feet.

In fact on the back side of the moraine of the Saginaw lobe which extends through Secs. 27 and 22, Verona, I have noted a bench and a change in the topography at the same level.* Finally, as indicated on the map, there are a number of kame-like gravel hills on Secs. 29 and 28, Verona, which reach nearly up to an altitude of 800 feet above tide, though the continuous benches are lower.

It is probable, therefore, that so long as the whole current had finally to pass down the valley of the Cass through Sec. 32, Bingham, the level of the eastern lake, Lake Whittlesey, remained practically constant, no matter how many different channels there were by which it started to leave the lake. This level so many observations point to as being between 800 and 810 feet above tide that we may be reasonably confident of those figures, the latter figure being probably the maximum. But when the lobe of the Saginaw moraine melted back so as to let the waters around behind the very heavy series of ridges which run north northeast from the southwest corner of Bingham the lake discharge found its way across the northwest corner of Bingham, half burying the clay ridge on the north side of Sec. 4, Bingham, in sand on the east side, and making heavy gravel deposits along the north side of Sec. 3, Bingham, then as the ice retired sweeping sand and gravel over numerous places in Colfax, Bingham and Sheridan, and passing southward out of the county in some well marked channels,* the new and independent outlets probably lowered the waters rapidly.† The first gravels on the back of the moraine are not very much lower than those previously mentioned, but as we go northwest in Sheridan the gravels appear at lower levels, down to 770 feet, in a long ridge on Secs. 9, 10, 11, and 12.

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*799 ft. A. T. on center line of Sec. 22, 0.36 miles east of west quarter post.

We infer thus that as the Saginaw lobe retired from Bingham and Sheridan, the water level lowered rapidly in Lake Whittlesey. We have already seen that this appears to have been not before the Huron lobe had retreated to Verona Mills, and we must indeed almost imagine that at the same time that the Saginaw lobe withdrew across Sheridan township to the neighborhood of Popple, Sec. 6, Sheridan, the Huron lobe would withdraw from Verona Mills a little way. A withdrawal of a mile or so leaves, as is obvious from the map, a clear connection around the end of the rough and irregular agglomeration of conical hills which mark the junction of the two lobes. Gravels are found on these hills clear to the top (855 feet A. T.), but they seem to be largely overwash gravels from the surface of the ice, very likely intermixed at lower levels with material brought down by the glacial stream from the north.

Along north of Verona Mills on Sec. 18, Sigel, are gravel pits for road mending, which Mr. Taylor takes to be kame gravels. The first well marked and continuous beach which extends around north of these hills is at 774 feet altitude (Taylor 775 feet).‡

This is according to Taylor the Upper Forest Beach, and it can be traced continuously as indicated on the map (Plate VIII), spreading broadly over the uplift of the Marshall sandstone escarpment passing about a mile east of Ruth, and decreasing in altitude at the south line of the county down to about 750 feet above tide (756 A. T. on Sec. 7, Sherman). It may occasion surprise that these old beach lines should not follow contour lines, and remain a constant distance above the lake throughout. The general testimony of observers is, however, that this is not the case, and there are a number of possible causes to account for it,* but the gravitative attraction of the ice sheet, which would have its greatest effect on a body of water lying between two lobes of the ice front, seems quite sufficient to account for the rise so far as seen in this Forest Beach in this county. When we trace this beach level off from Verona Mills to the southwest we find it again falling slightly. We can trace it quite well, as shown on the map, through Sec. 12, Verona, and across the northwest corner of Sec. 14, faintly up the valley of the Willow, very well marked in a little bay on Sec. 21 and clearly marked on a slope well sprinkled with boulders across Sec. 20, to the southeast corner of Sec. 19, near Badaxe. Here there seems to have been an opening into a large lagoon or sound in which marl was deposited, shallow and not over fifteen or sixteen feet deep for the most part. The altitude of its bottom is 754 feet above tide. A low island with marked dune sand ridges rose above the lagoon in the northeast corner of section 34, Colfax, and from Badaxe to Popple, followed by the old State Road, runs a moraine ridge, which rises somewhat above the Forest Beach level in the northern part and is flanked by well marked terrace gravels at the level of the Upper Forest Beach (765 feet A. T.), and often buried by them. The level of Webber's gravel pit near the southwest corner of Sec. 13, Colfax, gives a good opportunity to obtain the level of the beach here quite exactly with reference to the Saginaw, Tuscola and Huron R. R.[*] Down near Popple we find a number of hills, which appear to have protruded above water, and the bench marks of the first beach are scored upon their flanks.[†] Thence the Upper Forest Beach can be traced through Secs. 11, 14 and 13, Grant, down to another sound, a remnant of which is Mud Lake. It reappears again on Secs. 28, 29 and 31, where the moraine once more was above lake level, and where it is at an altitude, as previously stated, of about 744 feet above tide.

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*Sec. 34, Grant, Sec. 32, Sheridan.

†Compare.
Sec. 8. Bingham, 0 paces N., about 500 paces W., sand 804 feet?
Sec. 7. Bingham, 0 paces N., about 600 paces W., about 808 feet?
Sec. 7, Bingham, 0 paces N., about 1850 paces W., sand ridge at 780 feet A. T.
Sec. 6, Bingham, sand ridge 200 ft. wide, at 771 feet A. T.
Sec. 19, Bingham, 368 paces S. of N. W. corner, bottom of steep bouldery ascent with stratified gravel at 788 feet A. T.
Sheridan, southside of Sec. 21, sand ridge at 788 feet A. T.
Sec. 24, Sheridan, about 200 paces E. of S. W. corner, gravel at 780 feet A. T.
Sec. 19 and Sec. 30, Sheridan, esker and kames at about 785 feet A. T.

‡Just N. of S. W. corner of Sec. 18, Sigel, also close to S. E. corner of Sec. 17 and near the east quarter-post of Sec. 21, and for two miles east a gravelly strip cut through by a drain the altitude of whose bottom is about 765 feet.

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*The following are some of the causes:

(1) The ice sheet may have attracted the water toward it, just as a plumb line is deflected by a mountain near by. This would give a slope relative to the present level increasing to a maximum at the margin of the ice front, and not over 1.8 ft. per mile for a sheet 10,000 feet thick (the Greenland ice sheet is about 9,000 feet thick) while the average slope for 69 miles from the border might easily be 0.4 feet per mile. See Woodward in sixth Report U. S. Geol. Sur., 1884-1885, p. 295-296, also U. S. G. S., Bull. 48, p. 66. It is found generally true that the slope of the old shore lines rises toward the ice. It is to be observed that in the case just before us of water lying between two lobes of the ice, we have a case of maximum effect something like that discussed by Woodward of a canal in the ice sheet near the margin, where the equipotential surface within the ice sheet is to be considered.

(2) The shifting of the volume of the ice sheet, if not symmetrical to the pole would displace the earth's axis of rotation, relative to the solid crust, but a rough investigation shows that this would have a negligibly small effect.

(3) The weight of the ice cap may have bent down the crust upon which it lay during the ice period, which may be supposed to have been uplifted again when the ice retired. But here it is to be noted that we cannot compute this effect as independent of effect No. 1. If the ice sheet depressed the earth beneath it it would have a correspondingly less effect in drawing the water up toward it. In a certain sense the first and third agencies might be inferred from the same phenomenon, by two different ways of looking at it, for the raising of the water surface by ice attraction, would produce an apparent subsidence of the land. The test between the first and third effects would apparently be the rapidity of the apparent uplift of the land. If it continued after the ice sheet had disappeared, it must be really a land uplift. Cf. Upham (23d Annual Report, Minn. Geol. Sur., 1895, p. 162) on Epeirogenic Uplifts. So far as the difference in level of the old water levels and the later water levels is concerned, this effect would be practically the same, to the order of approximation of Woodward's solutions.

North of Badaxe, running from the southwest corner of Sec. 7, Verona, through Secs. 8, 9 and 10 to 11 is a low clay ridge, heavily aproned with gravel on the south side, which rises a little above the Forest Beach level, and seems to mark the line of the ice front at one stage in the time of the Forest Beach. This seems to be practically the same moraine which passes north and west of Popple and northwest of Mud Lake. At the beginning of the time of the Upper Forest Beach this moraine was probably largely under water and kame gravels were extensively formed in a broad shallow sound which faced it and was later resolved into a series of lakes (indicated by shell marls under the present swamp) of which Mud Lake is the only surviving representative. By the end of this time the connection between the two sides of the "Thumb" was so open that the water level was practically identical in both, as is shown by the fact that the gravels at the foot of the ridge north of Mud Lake are at practically the same height on each side. Hence the retirement from this ridge, the last place in the county where the ice front kept above the water, made no material difference in the lake level. I was at one time inclined to think that the retirement from this point might have caused the slight drop to the Lower Forest Beach level, but the double beach line appears well marked on the northwest flank of the Mud Lake ridge.

This Lower Forest Beach is at times somewhat more than ten feet below the other, and can be followed around with it very well, and the two beaches may mark merely two high water stages easily due to climatic variations. Through Sigel township the lower follows the upper beach quite closely, but extends out over the flat lands of Lincoln township much farther in long sand spits or barrier beaches at an altitude of about 757 feet above tide (on the south side of Secs. 20, 21 and 29 and 35, Lincoln, on the east side of Sec. 31, with a spur also, and on the east side of Sec. 33, Lincoln). Through Colfax township there is a broad sandy terrace whose upper margin is at about 749 feet above tide. This second terrace is clearly marked in the north corner of Grant township at 739 feet above tide, and about 6 to 18 feet above the general broad sandy level over which it looks.

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[*] The level of the surface of the pit is about 180 feet above lake. The average of eight observations on the gravel bench not far from Badaxe gives 182¾ feet above lake.

[†] S. line of Sec. 31, Colfax, and Sec. 36, Oliver, also on S. line of Sec. 1, Grant, where they can be followed some distance with the eye. Altitude, average of four observations, 172 feet above lake or 754 feet A. T.

The lake thus formed by the running together of Lake Saginaw and Lake Whittlesey has been called by Taylor, following Spencer, Lake Warren. In all probability for quite a while after communication was opened around the end of the "Thumb" the ice front remained not so very far off, and possibly streams issuing from it may have laid down some of the ridges which we find especially in Lincoln. There seems, indeed, to be one ridge in particular which begins on Sec. 11, Verona, opposite the head of the Willow Creek valley, which, as we have said, was probably filled by a river from the ice. This ridge passes thence through sections 2, Verona, and 34 Lincoln, and thence northwest to Secs. 32 and 33 Lincoln, and thence at first north then northwest to Sec. 25, Hume, which, though it has not been traced continuously, seems to be continuous and to be running down hill. It must, if so, mark the successive dumping grounds of a stream issuing from the ice sheet as the latter retired beneath the lake surface.*

Of course such a ridge would be more or less washed over by the waves as the lake level gradually settled. It may, however, be merely a sand spit out in an eddy at the end of the point. Whether this particular line of sand and gravel is rightly explained or not, such streams must have brought down much sand and gravel for the waves to dispose of, and we have evidence of that and also of a strong westward current in the accumulation of such sand and gravel deposits quite extensively all along the westward face of the emerging plain.

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*Such a ridge is called an esker and it may be noticed that the supposed esker is in continuation with the line and curves of the upper Willow Valley, and may be due to the same river. It is in a general way at right angles to the ice front and in the direction of the ice retreat. Another somewhat similar ridge appears on Sec. 30, Sheridan.

These deposits of sand were also supplemented by the deltas of the streams which drained the lagoons of Verona, Colfax, Sheridan and Grant, later converted into a series of lakes. Under the swamps which now fill the places of these lakes we find shell marls which may be referred to this epoch, and plainly indicate a colder climate than the present (see Chapter X, Sec. 2). The most noticeable delta of this kind is that of the upper Pinnebog on the north side of Sec. 31, Colfax. Westerly winds may have aided the waves in piling up the ridges on shore. At any rate we find a broad sandy belt extending practically from Robinson's hill in Sec. 13, Dwight, down to Brookfield township, and lying about 710 feet above tide, in which sand and strips of country covered with boulders are abundant. The indications of a northward rise in beach levels rapidly disappear.*

§ 4. Lake retreat. Later terrace or recent epoch.

A temporary halt in the subsidence of Lake Warren seems to be indicated at about 725 feet above tide, after which the lake seems to have sunk more rapidly than before down to about 700 feet above tide. Then the subsidence must have been slower and sand ridges are numerous down to 680 feet above tide. It must have been held at this general level for quite a while, for we find in front of the 680 foot beach line that the drift has been scoured away in many places down nearly to the rock, so that the 670 foot to 690 foot contours are crowded together and a series of terrace benches have been cut on the east side of Robinson's hill on Sec. 13, Dwight. Sand ridges at about this level, i. e. 98-108 feet above the lake were found almost invariably where these contours were crossed, also delta sands near the rivers on both sides of the county. Most of the outcrops, except those immediately adjacent to the shore, are connected with this level. Frequently there are numerous boulders covering the surface of the lower land immediately to the west like the boulder pavement figured by Spencer.†

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*The sand ridges are, however, so near together in altitude that they are within the range of our errors in determining altitude, so that nothing can be said very definitely. Still in Lincoln numerous ridges fall within 145 to 134 feet above lake, in Meade within 153 to 133, in Colfax within 152 to 144 and one at 128 feet. In the north part of Grant the soil is sandy about 150 to 130 feet above lake, and in the south part of the township it is gravelly pretty continuously down to 125 feet above the lake; these facts may be accounted for by supposing that the upward grade toward the ice had largely disappeared before the lake had sunk more than thirty feet.

†Loc. cit. in Pop. Sci. Monthly.

Fig. 3 illustrates the boulder bench which lay just below low water and the series of ridges, the highest of which was, of course, somewhat above highwater, of Lake Warren at this level. The fact that the lake was thus held for quite a while from 672 to 692 feet above tide may be connected with the fact that that is about the lower limit for the Pewamo outlet. After free connection was established, it is natural to suppose that the lake would wear down the outlet, and its own level fall until the outlet had shrunk so as to be only sufficient to carry off the annual supply of water, after which the lake would remain relatively permanent. We call these beaches the Grassmere beaches since this general level is most accurately determined where it crosses the Saginaw, Tuscola and Huron R. R. near Grassmere, but it seems to be quite horizontal in its course around the thumb. From this level Lake Warren dropped rather suddenly to an altitude of 647 feet above tide.* What caused this drop, whether the opening of a channel around by Mackinaw into Lake Chicago, or some outlet across central New York down the Mohawk I would not dare to say definitely,† but the subsequent pause in the fall of the waters is well marked and we may follow it, from the swamps of Brookfield township past Elkton, where the beach gravel wraps around a low waterlaid moraine ridge of till, which runs from the northwest of Oliver to the northeast and is the last relic of the ice front that we notice, on to Port Austin where the beach skirts the hill on Sec. 31. This level is also visible on Sec. 3, Dwight, and probably the prolonged lake action during

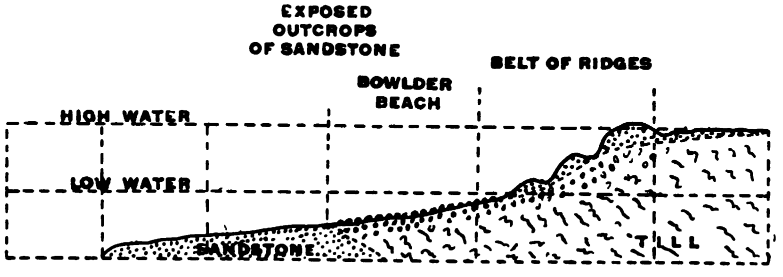

Fig. 3. Illustrates the relation of sand and gravel ridges, boulder benches and flat sandstone exposures to ancient water levels. South line of Sec. 3, Meade Tp.

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*Levels back of Port Austin; also the S. T. and H. R. K. near Elkton. There are also delta sands and gravels on the Pigeon River near Sec. 23, Winsor, and on New River in Huron Township, and in Huron Township the 640 foot contour is crowded up to the 650 foot contour.

†Cf. Fairchild's recent announcement of beaches in Lake Warren at low levels. Bull. Geol. Soc., Am. Vol. VIII, p. 271.

this pause had something to do with exposing the outcrops on Sec. 1 of the same town. In Huron township a well marked bar at this level connects the hills on Sec. 3, and it is apparently a prominent sand and gravel beach below the Forest beaches on the eastern side, being traceable quite continuously down to the southeast, until near White Rock it is only three-fourths of a mile from the Lake.

As the streams on the west side of the county come down to this level they emerge from rather deeply cut valleys to quite shallow ones, and are deflected to the north. The contrast between the valley of the Pinnebog where it crosses the Saginaw, Tuscola and Huron R. R. near Elkton, with its valley either above or below,—a change from a valley 20 or more feet deep to one only 3 to 10 feet deep and broad and vague, is striking,—and the same phenomenon is noticeable in the Pigeon on Sec. 36, Winsor, and other streams. This fact indicates that the water stood between 700 feet and 650 feet so long as to give the streams a chance to cut pretty well down to that base level, after which time the water level sank so suddenly that the streams in deepening their valleys had to work back from a mouth quite a distance off.

The next halt of the water below this level is probably a short one indicated by the bench on the Port Austin hill at 635 feet above tide, and by some sands and gravels in the south part of Winsor (T. 16 N., R. 10 E.), and the waves probably just broke on the top of the limestone ridge in Sec. 5 of the same township, and cleaned off the till therefrom.

There is no other marked halt until we reach the most pronounced one in the whole series, correlated by Taylor as belonging to Lake Algonquin, a large lake which stretched from Lake Superior to Lake Erie and discharged over Niagara, though the land was so much lower to the north at that time that the water of Lake Algonquin would have discharged by North Bay down the Mattawa valley (Canada), had not that valley been still occupied by the rear guard of the retiring ice sheet. Like the present lakes it may have had its changes of level from season to season and decade to decade, which seem to be confined within a range from 20 to 25 feet above the present lake level, say 607 feet above tide.*

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*Compare the ridge roads of the R. R. Surveys, Chapter III, Sec. 5. The tops of the ridges of sand are evidently piled above what was then the water level, and observations on the highest beach line at Bayport agree with that at Port Austin and with the general altitude of the marshes behind the dune lines, in fixing the highest water line of Lake Algonquin at 25 feet above the 582 foot base

This level is marked on the west side of the county by an almost continuous line of dunes, whose crests commonly rise above 30 feet, and on the other side of the county by cliffs. Only in a few cases, as just south of the lighthouse on Sec. 12, Huron, T. 18 N., R. 14 E., and again north and south of White Rock have the cliffs of the present lake been cut back so far as to overtake the cliffs cut at this higher level, while the dunes of the higher level quite hold their own in comparison with the dunes of the present area. Back of the dunes are extensive marshes lying near the 25 foot level, through which the streams meander. All these are signs of a length of halt much longer than anything that we find above.* Between this and the present lake level it is not uncommon to find four beach crests among the most noteworthy of which is the one followed by a "ridge road" about 14 feet above lake level.† The water line probably lay a little lower, at 10 to 11 feet above the 582 foot datum, at a time perhaps within the range of tradition, as I hear from Dr. W. C. Wright, of Unionville, that the Indians had a tradition of rowing over Pine Island, now 11 to 13 feet above the lake. The high water line of 1886 is well marked in a crest from four to seven feet above the present lake level, and so we come down to the level of 1896. Since that time the water has been rising again somewhat, but the last report of the U. S. Engineers states that since 1886 the St. Clair outlet has been rapidly cut down.

It should be said that Taylor thinks that at the close of the era of Lake Algonquin the Mattawa valley channel was opened and the water of the lakes was for an extensive period (the period of Lake Nipissing) lower, and here and farther south has recently readvanced. This I believe to be true farther south, but as Taylor's paper shows, Huron county lies near his nodal line, where there has been no such readvance for Lake Huron. According to his theory, which in general I accept, during the time of the lake that

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(A. T.). There is frequently a second crest a little lower. On the east side of the county the boulder bench or terrace, which must have been below the water line and faces cut cliffs which frequently rise 40 feet and more above the lake, is from 17 (Harbor Beach R. R. station) to 20 feet above the lake. Occasionally above this main bench we can see small benches, old beach crests, at 23 and at 28 feet, respectively, above lake. The streams broaden out and meander in their valleys at this level also.

*Taylor, priv. com., Feb. 11, 1897, correlates this with the Algonquin beach, but leaves open the possibility that it may also represent the Lake mentioned next, Lake Nipissing.

†Beside R. R. levels in Chap. III., Sec. 5, we noted also on the center line of Sec. 18, T. 15 N., R. 9 E., beach ridges 11, 14, 17 and 20 feet, respectively, above lake, and correspondingly, on Sebewaing river, terraces 2, 5, 13 and 18 feet, respectively, above the river bed. Around Harbor Beach the bench appears to be nearly continuous from 18 feet down to 14.

he calls Nipissing, since the present Lake Nipissing (northeast of Georgian Bay, Lake Huron) was at that time part of the Great Lake system, the land was so depressed to the north that the lakes drained to the sea through North Bay and the Mattawa valley, and owing to the tilting necessarily implied deserted the southern part of their basins. Huron county lies near the dividing line between the region where the old level of Lake Nipissing extended less far on the land, and the region where the level of Lake Nipissing was above the present level. If the lake level during the period of Lake Nipissing was lowered in Huron county it could have been but slightly lower, for if there had been a long lower stage we should find the rivers near their mouths had cut down to it, and then the rise of the coast would flood their valleys, producing such a type of coast as we have in Chesapeake Bay, or on the southern shore of Lake Michigan or in Monroe county on Lake Erie. See Part I of this volume. Of such a shore there is no evidence. On the contrary many of the streams, the Shebeon, Willow, Diamond, Allen and others flow on rock bottom close to their mouths. In fact this is the rule rather than the exception, and at other points, as at Caseville, dredging has shown that rock is close beneath, and had the streams been flowing down to a much lower level any length of time, they would have cut back rock channels farther inland. On the contrary the geological evidence is that the latest movement is what Prof. Gilbert has recently shown by measurement, to be still in progress,[*] viz.: an uptilting of the lake shores to the north-northwest. By carefully comparing the elevation of certain fixed points with the mean water level for the season in the summer of 1897, with the elevations of the same points above mean lake level determined by the Lake Survey years ago, he found the northeastern points relatively higher now than then in a way that indicated a rising of the earth's crust in a direction N. 27° E. about 0.42 of a foot per hundred miles per hundred years.[†] For instance, "Between 1876 and 1896, a point at Port Austin, Michigan," i. e., in Huron county which we are studying, "on the shore of Lake Huron as compared to a point in Milwaukee, on the shore of Lake Michigan" rose 0.127 of a foot or one and a half inches."[‡] The distance between these two points is 259 miles, or, in the direction N. 27° E., 176 miles. Huron county is distant fifty miles more or less in the direction north-northeast from the outlet of Lake Huron at the Saint Clair River, so that such tilting would produce along the shores of Huron county a rise of the land upon the lake of about 0.2 of a foot per century. We do not know how long this rate of tilting has continued, nor whether it is increasing or decreasing, but the fact above cited that so many of the streams have rock ledges close to their mouths seems to confirm the belief that the latest motion of land relative to lake in Huron county has been an uplift. Possibly more detailed study may lead Mr. Taylor to shift the nodal line for Lake Nipissing a little to the southwest.

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[*] Modification of the Great Lakes by Earth Movement, National Geographic Magazine, Sept. 1897, viii, No. 9, pp. 233-247.

[†] See Chapter III, Sec. 5 (a), for correction of these figures.

[‡] Loc. cit. p. 244.

§ 5. Time estimates.

We have now finished our account of the various stages in the retirement of the lake. By comparing amount of cutting on the one side, and amount and volume of beaches and dunes on the other at the different levels we can form some estimate of the relative time during which the water lingered (Fig. 4). Of course no accuracy can be claimed for such estimates. They are only the first rough approximations. Still it seems quite clear that the work below the 40 foot level is more than equal, measured either by cut or fill, to all that which preceded it. To get some idea of the unit of the time scale one way would be to survey Mud Lake and see how much it had shrunk, and been filled since the meanders of the original Linear Survey, and then if possible find its original extent. Rush Lake is also obviously shrinking, but is much younger.

Another way would be to find the amount and the rate of erosion on the eastern shore. The Wisconsin Survey carefully resurveyed the meander lines along Racine and Milwaukee counties, and found an average rate of erosion of 3.33 to 2.77 feet a year from 1836 to 1874. Dr. Andrews found, even rejecting erosion of extraordinary rapidity, erosions from 17 feet a year down to 0 averaging about 5 feet per annum around Chicago.*

For the eastern shore of Huron county we have no such close estimates. In fact the general impression is that the shore has been gaining upon the water. But as Plate V shows, for the ten years before 1896, the waters had been lowering rapidly. Again opposite Harbor (Sand) Beach the shore is protected by the great artificial breakwater erected by the government at a cost of $2,000,000 and a filling in has

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*Leverett, Bull. No. II, Chicago Acad. of Sciences; see also Crossman's chart.

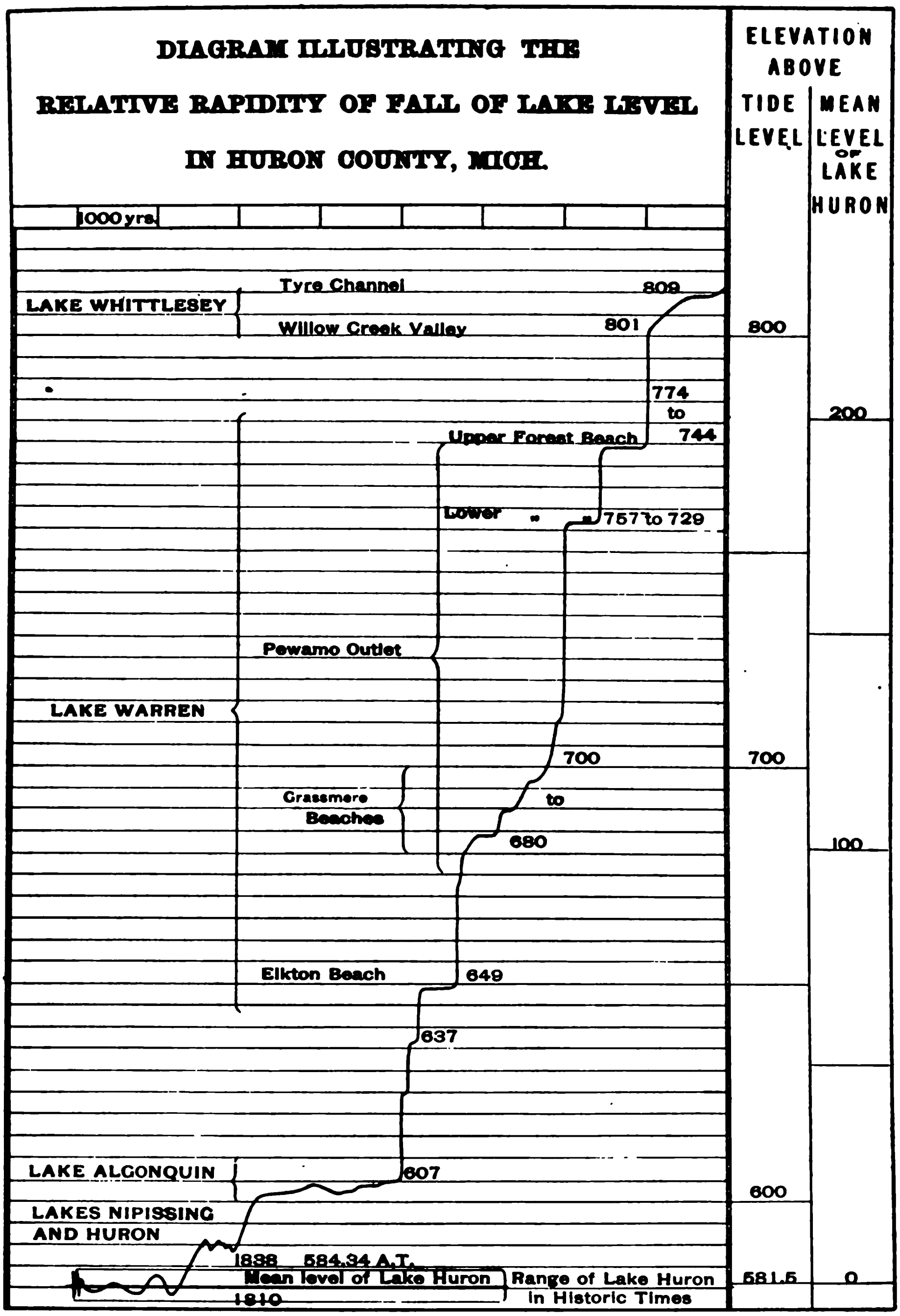

Fig. 4. Illustrates the relative strength of the water lines at various levels in Huron county, Michigan. The altitudes given at various parts of the curve are above tide, lake level being 582 feet above tide, according to Gannet. The altitudes are indicated on the vertical scale while the horizontal scale represents the relative strength of, respectively, the time required to produce the various shore lines. Names of lakes and water levels, etc., with the exception of Grassmere and Willow valley, are after Taylor.

been caused. Mr. Geo. W. Jenks says that a strip of an average width of 50 to 100 feet has been added in his recollection,—the last twenty years or so. A large double tree, which in his boyhood was on the crest of the beach not over fifty feet from the water, is now 140 feet from the limit of vegetation or 145 feet from the water's edge according to measurements that I made in Sept., 1897. The old Land Office notes make the distance along the north line of Sec. 12, T. 16 N., R. 15 E., 50.25 chains, i. e., 3316.5 feet. The county atlas gives by scale 3560 feet, and the careful plan of Sand Beach harbor prepared in 1889 by the U. S. Engineers from work between 1885 and 1888 makes the same distance 3600 feet, showing a decided gain of land over lake, especially as the lake was highest in 1885. But this line is close to the mouth of a stream, and perhaps influenced by its delta. The various successive blue prints by the United States Engineers show plainly the accretions year by year. But when we come to compare with more distant times and especially with the records of the first Land Office surveys, which are not very accurate, however, in 1834 and 1835, when the water was as low as in 1896, we find a very different state of affairs. The indications are of greater or less erosion not of gain. Let us cite a few facts. Mr. J. H. Tucker, one of the oldest surveyors of the county, reports a general erosion of the land; that to the north on the town line where the quarter post originally stood on the land the shore now comes 40 rods this side of it.* The elder Mr. Jenks bought a lot which, according to the government notes, contained 65.50 acres. By 1880 this lot (3, Sec. 36, T. 17 N., R. 16 E.) had dwindled on resurvey to 54 acres, implying if both surveys were accurate and took the shore line in the same way a retreat of 380 feet or 8.43 feet per annum. To the south of the breakwater near the summer resort, on the west line of Sec. 7, T. 16 N., R. 16 E., the line from the corner to the water was in February, 1896, 1730 feet to the edge of the bluff plus about 30 feet to water, a loss from the original survey of 50 links. On the south line of the same section, 7, the line was 20 to 30 links short. This loss in spite of the low water of 1896 and the recent accretion due to the protection of the breakwater shows that there must have been considerable cutting before, amounting to between 100 and 200 feet, i. e., for the fifty years, 1835-1885, from 2 to 4 feet a year.

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*But the government notes, April 14,1835, show 34 chains to Lake Huron.

As we approach White Rock, just before we come to the high 35 foot bluffs I saw a large pine stub standing erect in the midst of the waters, evidently left from the land waste. The 35 foot bluffs are evidently being attacked vigorously by the waves. Some of the residents attribute the wasting away of the cliffs to the frost's action in splitting them off in the spring. In their observation they are doubtless right, but inasmuch as the cliffs are about as steep as they can be now, it is obvious that the waves break up and carry away the debris of the slips as fast as the frost feeds it down, so that the frost merely acts as assistant to the water. The most detailed information gathered concerns the lot of Mrs. Mary Van Wormer (south part of lot 3, Sec. 20, T. 15 N., R. 16 E.), where a whole barn and barnyard have disappeared in the last ten years. As they cannot plow too close to the edge of the cliff all along here for fear of slipping over, it is easy to note each year that the tracks for the previous season are from 3 to 6 feet farther out than they dare plow. A lot of two acres which lay in triangular shape below the higher bluffs at their northern limit and at the Algonquin 18-20 foot levels is practically gone, the width from the road being not more than 50 feet. This would indicate an erosion of 6 feet a year, or if we take the two acres as a strip from the full width of the Van Wormer property (6 chains) it will still mean an erosion of not less than 220 feet or over 3 feet a year. In September, 1897, the distance of the brink of the bluff from a basswood tree on the east side of the road where it first mounts from the Algonquin level was 76 feet. South of White Rock, on B. Hiduler's property (Sec. 32, T. 15 W., R. 16 E.), we find similar erosion and the rates stated are similar, 3 to 6 feet a year.

Up in Huron township, Sec. 12, T. 18 N., R. 14 E., Mr. Tucker reports that a resurvey ordered by the supervisors showed that a man was paying an undue amount of taxes, owing to the great retreat of the arable land. This is in the neighborhood of the Point aux Barques lighthouse and is another place where the present cliffs have cut back beyond the Algonquin, and it may be noted in this connection that whereas the Lake Survey report them as 40 to 60 feet high, in 1896 by tape line they were but 32 to 35 feet high. *A propos* of the tree stubs left standing in the water as witnesses of land waste, Mr. Jos. Grice who was employed under the United States Engineers reports that such stumps were found in water near the Harbor Beach pier, and also just north of the town line, apparently off Mr. Jenks' lot above mentioned, at a point known as Drowned Point from the stumps thus left. These may, however, be the relics of an island known as Elm Island on the old maps, on which a number of islands now no more are put down. He says moreover that the building of the breakwater caused an extra cut of 15 to 35 feet along the shore to the north of its end for the first few years, until it was checked by the fall in lake level, 1885-1896.

Thus, as the general situation of the eastern shore of Huron county is not unlike that of the eastern shore of Wisconsin, so the rate of erosion, judging from the scattering and not very reliable figures above given, seems not dissimilar, perhaps three feet a year as an average, and almost certainly more at exposed points. If now we extend the general slope of the land from Ruth to the White Rock bluffs, a slope of about 20 to 25 feet per mile, out to the lake level, we find that it will strike the same about a mile and a half out. We also find, just as Andrews found, about four miles out a bulge in the lake bottom, and then a comparatively sudden drop, the bulge being nearly hit by the grade line aforesaid. The cliffs near White Rock were not all cut at the present lake level, but a slice was taken off at a level about 20 feet above the present nearly as far back as the present bluffs, and then successive slices farther down, but the erosion has been much faster at the present level, or the time so much longer that the action has overtaken all previous cuts. If we assume the cut to have been at a uniform rate and to have been from the grade line of the general country the cut we have would have taken about 2,800 years, at a rate of 3 feet a year. But as the recent erosion is extra deep at White Rock, it may be fairer to assume an erosion somewhat higher. If we call the time an even 2,000 years the average erosion would be only about 4 feet per year.

If we look at the Lake Survey chart of Saginaw Bay and part of Lake Huron, or at the field sheets of Sanilac county, we shall see the Algonquin 25 foot bench well indicated and running from half to three-quarters of a mile back of the present shore line. But as it is so much higher than the present bench, it would cut the grade line perhaps a mile nearer the shore, so that the total breadth of the notch cut at this level may have averaged a mile or less, not far, perhaps, from the average breadth of the notch cut at the present level, as the notch at White Rock is probably extra deep. We may also compare the breadth from the present shore line out to the three fathom line. If an equal amount of erosion has been done at each of these levels, and the mean rate of erosion was the same, and we see no reason why it should have been materially different, say 3 feet a year, each notch of a mile or less at a rate of 3 feet a year would have taken somewhat less than 1,760 years. This would imply a rate of 4½ feet at White Rock to produce strict accordance.

Taylor's estimate for the duration of the present lake system from the rate of erosion of Niagara is 2,700 years. In order to bring our figures into any accordance with his (the factor of safety which he introduces by increasing 2,700 to 5,000 to 10,000 seems to be unnecessary), we must assume that the Nipissing erosion was at a slightly lower level and has been hidden by the debris from the later cut at a higher level, so that the time of the Nipissing Lake is not accounted for in our study, just as it is omitted in the work of Dr. Andrews who gets for the duration of the present Lake Michigan at various levels, from 13,000 to 3,000 years, or in another way, using the rate of erosion determined by the Wisconsin Survey, some 4,700 years. I must confess that the character of the stream valleys and the frequent rock exposures near their mouths leads me to believe that in Huron county, Lake Nipissing and Lake Huron were at nearly the same level, and that the cut at White Rock includes the efficiency of them both. In that case the total time since the fall below the 40 foot level in Huron county could be confined within 4,000 years in accordance with all we yet know. A certain check on our results may also be derived from Gilbert's measurements of fluctuation of relative level aforesaid. From the relative strength of the beach lines, we may feel sure that the lake level has remained more than ordinarily constant within the range through which it has fluctuated in the century. Therefore the rate of change of land level must have been below the average. Thus, unless the rate of change found by Gilbert is abnormally high for the century (which of course it may be) it must be below the average rate of change during the emergence of Huron county from under water,* and then supposing that no oscillations of lake level which have occurred have checked its efficiency as a cutting agent, according to the figures at the end of the preceding section the emergence of the last 25 feet must be confined within the past 12,500 years (25 ÷ .2 feet per century). We may note that Gilbert's rate of tilting would, if uniformly continued back into the past, change the present lake level into that of Lake Nipissing (7 in. per mile rise N.) in about 14,000 years. In the same way the apparent rate of lowering of the water at the mouth of French River would point to 14,400 years since the water stood at the level of the Nipissing Beach there, and that was the outlet of Lake Nipissing.

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*All the above expressions are applicable to Huron County only, and do not apply to other counties.

In Fig. 4 I have constructed a curve giving my impression of the relative importance, i. e., duration of the shore lines at different levels, taking into account not only the beaches, but the cutting on the east side, and the character of the river valleys. Perhaps it is too daring to attempt such a line which must of necessity indicate more than the facts warrant, though Mr. Taylor agrees with me in the general proposition that there has been more cutting and more time indicated below the 40 feet level than above, but it gives to the eye at a glance my general estimate of the strength of the several shore lines. It may in a rough way, too, suggest, though it was not drawn for that purpose, the relative duration of the several stages of retreat. We see from it that if we assume the time since the fall below 40 feet above present lake level to be 4,000 years, it will be easy to crowd the remaining fall into an equally long interval.[*]

We see thus that with the scale of time as above suggested, it would be only some 8,000 years since the ice sheet left Huron County. We may double this time and still be in the dawn of history, so that it is not too much to say that the departure of the ice sheet may have been coeval with the great tide of migration of the human race, which in these latter days is just completing the circuit of the globe.[†]

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[*] Dr. Andrews also finds that around Chicago the combined bulk of the beaches of Lake Chicago, which, in our diagram, correspond to all above the 40 foot level, and a little more, are about equal to those of the present shore line taking it out to where the water reaches a depth of 24 to 36 feet. Here, however, again according to Taylor the Nipissing is far below present lake level at Chicago, and hence the time of its work should be deducted.

[†] Estimates of the time since the departure of the ice sheet vary widely, but the present estimate, which has little value, agrees with the shorter estimates of time. Compare Upham's discussion of the whole subject, with references to others in the 23d Annual Report Geol. and N. H. Survey of Minn., 1895, and Taylor in Bull. G. S. A., 1898, IX, pp. 59-64, also Moraines of Recession, Jour. Geol. (1895). July, August), V, p. 422, from which paper at least 20,000 years can be inferred for the Terrace epoch in Huron County.

The most uncertain factors in the discussion above are:

(1) The assumption that all the erosion of the lake in the time in question is above present lake level.

(2) The assumption that the rate of erosion of the past sixty years is a measure for that in the more distant past. Now we know that it makes a great difference in the activity of the lake, whether it is rising or falling, and generally, as Taylor remarks, the action is most energetic when the lake is rising. But the period we have studied is long enough to have admitted of several rises and falls due to climatic variations, while according to Gilbert the movement of the earth crust and the erosion of the St. Clair River now tend to produce a slow fall of the lake such as might easily be supposed to have continued since Algonquin time. The more remote we suppose that time, the slower the mean fall must have been than the present rate, so that the erosion would be likely to be quicker. I cannot see that our rate of erosion assumed is more likely to be in error one way than the other.

Of course there have been times when instead of erosion there has been building, and we have made no allowance for them. But there have been such times in the last 60 years, notably the last ten, and climatic variations have undoubtedly produced these alternations all along.

Such considerations only warn us to what a range of error all figures are liable without enabling us to improve those we have given by any change derived from data wholly within the county.

CHAPTER V.

STRATIGRAPHY, DISTRIBUTION AND STRUCTURE OF THE ROCKS.

§ 1. The Cuyahoga or Coldwater shales.

We have in a previous chapter described the character of the rock column. It now remains for us to consider how these rocks are distributed through the county, what modifications they undergo, and what the indications are of their geological history, and, without trespassing too much on the material of a later chapter, what are their characteristics from a practical point of view. In this history we begin with the underlying oldest exposed beds, the blue shales of the eastern coast. Occasionally thin seams of sideritic grit are intercalated, which grow thicker and more abundant near the top. They are at present exposed only near the eastern shore and in the Willow Creek section. Under the cover of drift or in deep wells they are characterized by the lack of good water from the rock. Speaking generally, it may be said that within the region colored on the map (Plate VII) as of this formation, wells in the rock do not yield a satisfactory supply of water, either in quantity or quality, for it is often brackish. The dip[*] of this formation estimating from the correlations of the deeper wells, is not far from 40 feet per mile and is in a general way on the west, but the line of strike shows a veering from about S. 31° E., which is the strike of the *Romingerina julia* beds from near Point aux Barques, down to the Willow Creek to the south. The dip seems to be greater toward the east. The character of the sediments is quite uniform, as mentioned above, and with what is known of similar deposits elsewhere, we may infer that they are composed of the finer detritus brought down by sediment-laden rivers from the Laurentian highlands of Canada, and from regions which contained much iron, i. e., region of hornblendic rocks. The sea was not very deep and the shore was either not very steep or was yet quite a distance from the present limits of Huron county.

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[*] Dips: From New River to Grindstone City (1010 — 900 or 1080 — 1000 to 1029), is 47 ft. per mile. From White Rock, which is 560 + 505 feet below the top of the Napoleon, to Sec. 35. Sebewaing, is 39 miles; altitude of the top of the Napoleon in the well there 502 A. T.; altitude of the well at White Rock, 592 (?). Whence (560 + 505) × (592 — 502) + 39 is 29.6 feet per mile dip from White Rock to Sebewaing. From Sebewaing to Ruth, taking the top of the ridge or rock escarpment near Ruth to be the grindstone or the Point aux Barques sandstone, 70 feet above the bottom of the Marshall, we have 505 perhaps + 70 — (592 — 740) + 6 = 59.5 to 71 feet per mile. If we take the bottom of the Marshall series in the flowing Badaxe well, Sec. 19, Verona to be at 820 feet down, i. e. 437 feet A. T., subtracting this from 592 + 396, since the Harbor Beach well begins about 396 lower, we have 551 feet in 16.8 miles, or about 32 feet per mile. Similarly to the edge of the rock escarpment at Sigel or Allen Creek would be (750 — 437) + 11 = 29 feet per mile. The strikes are indicated on the map, Plate VII, with the dip assumed in finding them in feet per mile.

The indications are that the rock surface in this region is nearly a plain, or rather a gentle slope from the ridge or watershed made by the more resistant rocks of the next overlying series. The more important wells that strike this formation, are those at White Rock, Harbor Beach, New River, Grindstone City, Port Austin, Port Crescent, Caseville, Bayport, and Badaxe. The more important outcrops are already partly described in the geological column; additional notes are as follows:

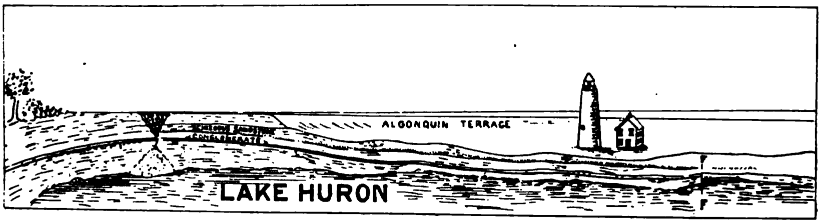

Fig. 5. Ideal view of Point aux Barques lighthouse, showing the conglomerate and the fault. The lighthouse stands on the Algonquin terrace, but to the left, south, the present lake has cut back farther than Lake Algonquin.

(1) The lower Willow Creek valley gives a nearly continuous exposure largely described in the geological column.

(2) The Point aux Barques section (see geological column, Plate I, and Fig. 5. Specimens No. 19044-19083). In this section we see as we go north and northwest that the beds run downwards from 15 feet at the south end of the bluffs to 6 feet above lake, near the lighthouse. Just beyond the lighthouse the calcareous conglomerate disappears, and is replaced by another layer farther down, the exact and critical point not being exposed when we were there. But this is probably the point spoken of by Winchell where there is a fault, the most extensive dislocation seen south of Mackinac," as he says. The neighborhood of the fault would account for the abnormal dip of 1°

to 1½° to the northeast. The general relations are illustrated by the perspective diagram, Fig. 5, which is not drawn rigidly to scale. There are some errors in Winchell's account, as where he speaks of the lighthouse being one mile east of Willow Creek, instead of 2, and of the dip of the sandstone being southwest instead of northerly, which it is in reality. Southwest is of course the general direction of dip in this region. Rominger's description is more accurate (Geol. Sur. Mich., Vol. III, p. 73). The palæontology of this very important section is given at length in Chapter X, § 3. The shales of this section are also visible farther south in a number of ravines in Secs. 12 and 13, Huron, cutting the bluffs which are at an altitude of 30 to 39 feet above lake and overlook the Algonquin terraces.

(3) Port Hope. A sandy shale occurs along shore and 50 paces south of mill at the water's edge, also in the bed of Diamond Creek for a few feet above its mouth. According to Rominger it also occurs one mile and a half north of the town and in the lake bottom close to the dock. These beds appear to be palæontologically equivalent to those at Harbor Beach.

(4) Near Harbor Beach are frequent outcrops for two miles south practically continuous with the exposures at Rock Falls. Then again north of the town in trenches and ditches up to the town line (N. line of § 1, T. 16 N., R. 15 E.), the shales and bands of arenaceous shales heavily charged with carbonate of iron are exposed. The most widespread form in all this section from Port Hope to an exposure in a wayside ditch on the line between Secs. 30 and 31, T. 16 N., R. 16 E., is *Chonetes* (*pulchella* Win? =) *scitulus*, Pl. X, Figs. 1 and 2; other forms are *Productus lævicosta* and *Conularia gracilis*.

(5) Rock Falls. "The same beds with Chonetes and impressions of Goniatites are well exposed at Rock Falls, the ripple-marked surface of the ledges * * * being covered with Caudagalli fucoids in relief, as well as other singularly-shaped prominences of organic origin."* At the mouth of the stream (N. E. quarter Sec. 19, T. 16 N., R. 16 E.) the water flows over a ledge of shale, and shaly sandstone in alternating beds, with a fall of three feet. The full section exposed was about ten feet. A similar exposure was observed about a mile below this. (Gordon.) The fossils from this locality are Nos. 19146-19150, and palæontologically it is said by Mr. Cooper to be equivalent to the Moot's Run section in Ohio. These same beds oc-

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*Rominger, loc. cit., p. 76.

cur obscurely at the base of the Algonquin bluffs on and near the north line of Sec. 31, T. 16 N., R. 16 E.

(6) South of White Rock for about a mile occur arenaceous shale beds in steep bluffs of 25 feet elevation above the lake. The same beds are beautifully exposed for about an eighth of a mile in the creek near the center line of Sec. 32, T. 15 N., R. 16 E., and are finely jointed; one set strike S. 52° W. dip to N. N. W., a poorer set S. 70° E. Indistinct cast of fossils, among them Goniatites, are found on the surface of the arenaceous flags. (Rominger loc. cit., p. 76.) These shale bluffs are illustrated and results of tests of them described in Vol. VIII, Part I on Clays and Shales by H. Ries. See also Ch. VII.

§ 2. The Marshall sandstones.

By the time of the next series above, that great elevation of the American continent, which marked the close of the Palæozoic era, had advanced so that the shore line was immediately adjacent to Huron county, and sandstones and coarse rocks prevail. These rocks are far more porous than those which preceded them. The figures of the following table (II) gives some idea of the physical properties of these rocks in this respect. The rocks of this series can be readily traced, at least so far as the upper part is concerned, since they are the most prominent source of water in the county and have been pierced by numerous wells. The water derived from them is much freer from mineral matter than the water from the beds above and below, being so characteristic that Prof. Davis said he could recognize "sandstone water" almost by the taste. Within the area covered by this formation, therefore, one can be almost sure of obtaining good water soon after passing the line between surface and rock. As it passes under cover to the southwest it grows more salty, which is not surprising since the salt of the Saginaw valley is largely obtained from this very formation. But it is nowhere in the county undrinkable and the salt in the deeper wells is probably largely from imperfect casing out of the overlying waters. In Sec. 19, Verona, around Elkton, and almost anywhere near the shore level, i. e., not over 14 feet above it, it furnishes flowing wells, and in many cases where the wells do not flow, as around Owendale and Soule, they once flowed, but now the drain on the formation has lowered the head. It is rarely that the wells are cased deep enough. They should be cased at least down to the top of the Marshall to obtain the best results.

Table II. Physical properties of sandstones, etc. All weights are in avoirdupois ounces (16 to the lb.) per cubic foot and we have assumed that 1000 oz. of water = 1 cu. ft. (which is true nearer than the limits of error).

A. Character of rock.	B. Number of survey specimen.	C. Sp. Wt.	D. Weight wet.	E. Weight dry.	F. Porosity.
Napoleon sandstone: Babbit quarry	19161	2.8	2.839 ±27	2.067 ±57	27.2 ±3.0
Hat Point	19087	2.8	2,718 ±300	2,615 ±300	10.3 ±2.5
Do	19102	2.8	2,308 ±52	2,040	26.8 ±5.2
Grindstone (scythestone of the Huron Grindstone Co., volume computed from dimensions)	19017	2.61	2.420 ±50	2,280 ±20	14.0
Cass river grindstone	19152	2.57 ±.04	2.290 ±40	2,070 ±20	22.0
Arenaceous shale	19092	2.64	2.500 ±120	2,360 ±90	14.0
Fine grained conglomerate of Willow Creek	19108	2.59	2,520 ±240	2,480	4.0
Sandstone near Point aux Barques lighthouse	19046	3.18	2.850 ±50	2,700 ±50	15.0
Bayport limestone	19006	2.69±	2,690 ±350	2,690 ±350	....
Bayport limestone	Report Vol. V.	2.72	....	2,720 170 bbls.	....

The physical characters and subdivisions as they are shown along the north coast between Oak Point and Grindstone City are quite fully described in connection with the geological column. The Badaxe well affords the most detailed account to the southeast on Sec. 19, Verona. As we go southwest the lower part of the series seems to become less sandy, showing that we are going away from a shore line to the northeast, along which this formation was deposited, and the whole Marshall appears in the drillers' records as a hundred feet or so of white sandstone at top, very full of water, representing the Napoleon, or some part of it, and below this, "red rock," "paint rock," "iron ore" and similar expressions are used in describing it. We can trace this red rock so continuously along* that there can be but little doubt that it represents the Lower Marshall of the north coast. Red rock also occurs so constantly (separated by about 18 feet of blue shale), under the salt rock of the Saginaw River, that as I am informed by Mr. J. Coreyell, it is often referred to in contracts for boring wells. That the Marshall should be represented by red shales as we pass from the shore is quite natural, when we consider the very ferruginous character of this lower Marshall, due as I have suggested it may be to the fact that there were large areas of basic greenstones, hornblende schists, and similar ferruginous rocks in the region from which it was derived. In Winchell's 1861 report (p. 91) he was in doubt as to how the Saginaw well section should be correlated with the coast, and at that time he was inclined to regard the shale reached in the Saginaw well immediately under the brine sandstone as the "thickened separating shale lying between the Napoleon and Marshall Groups." In this I believe he was right. Later and very likely properly, in view of the evidence then before him, perhaps also influenced by Rominger's erroneous views as to the Huron county stratigraphy he seems to have swung to the other conclusion, and to have thrown together the Napoleon and Marshall, as one group under the name of Marshall. With the evidence before us I believe that the other alternative must be taken that the whole Marshall of Huron county is not represented by a hundred feet of sandstone beneath Bay City and Saginaw, but that the lower part becomes shaly, and not distinguishable from the formation beneath. In my report, Volume V, I followed Winchell's later view, but I would now draw the line, for example, in the Bay City well (Pl. VI) of that volume for the base of the lower Marshall as we have defined it in Huron county somewhere near 1285 feet.

Though the dip of the Marshall is in a general way like that of the underlying formation, it has several minor undulations at least in the top of the formation (see Fig. 6), and it is probable that these are, like those at Point aux Barques lighthouse and the Sebewaing coal mines associated with faults of small throw. The capping of Learned's hill on Sec. 31, Port Austin, seems to be left as a small synclinal, since we find on Sec. 35, 800 paces N. and 135 paces W., that the Leiopteria beds exposed in the bluffs of the Algonquin level, to the east of the road dip as much as 5° to northeast and along the shore we find between Hardwood Point and Flat Rock Point a blue shale which seems to be mixed with a breccia of angular pieces of the sandstones with which it is associated. It, too, seems to dip about 4° E.

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*See Sovereign's well, Sec. 30, Lake; Sec. 35, Caseville; Sec. 18. T. 16 N., R. 10 E.; Meredith's well in Oliver; 200—300 ft.; Elkton, Sec. 10, T. 16 N., R. 11 E., Pigeon, Sec. 11, T. 16 N., R. 10 E.; Mason's well at Bayport, Sec. 36, T. 17 N., R. 9 E.; at the bottom of Voltz's well 350 feet deep, Sec. 10, T. 15 N., R. 9 E., and in Beck's well, 490 feet deep, Sec. 16, T. 15 N., R. 9 E., both near Sebewaing.

Connected with this synclinal fold (from which Rominger may have derived his idea of the correlation of the Flat Rock, Hat Point, and Point aux Barques sandstones), may be the phenomena on Sec. 5, Bloomfield, along Willow River. As we follow this stream up from the section exposed at the bridge (p. 24), on Sec. 4, Huron, toward the south we find blue clay shales and arenaceous flags, undulating and more or less ripple marked but in general with southerly dips. As we pass into Sec. 9, Huron, thicker and coarser beds begin to appear above and gradually extend down to the water line, and sandstone balls (cemented with kidney iron ore), are common. By the time we come to the south line of Sec. 8 there is an overhanging conglomerate with thinner slabby sandstone underneath, and some 300 feet farther south, there is 12 feet of sandstone which might at first sight be correlated with the Point aux Barques sandstone. This it is not, however, but a coarser facies of the grits of the grindstone quarries, for south of and above it we find the well marked zone of *Camarotoechia camerifera*, and *Romingerina julia*, just as it occurs above the grindstone quarries, on Sec. 26, Port Austin. Besides we can trace the Point aux Barques sandstone along continuously by well records and by outcrops on Secs. 22 and 35, Port Austin, and Sec. 1, Dwight, and we find it succeeding the *R. julia* zone farther south in Sec. 20—appearing first at the top of the bank and gradually working down. The *R. julia* zone can also be plainly recognized in a well sunk near the north quarter-post of Sec. 21, Huron, and gives our opportunity of most accurately determining the general strike for this region, viz., N. 31° W.[*]

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[*] In Port Austin on the north line of Sec. 26, the *C. camerifera* zone is from 14 to 18 feet above lake; on Sec. 17, Huron, it is from 48 to 58 feet above lake and on Sec. 21, Huron, about 60 feet above lake. Hence we must allow for difference of altitude and for a dip of some 30 to 50 feet per mile in estimating the strike. Also from the Point aux Barques sandstone, which crosses a little north of the north corner of Sec. 27, Port Austin, and also near the south quarter-post of Sec. 26 and the southeast corner of Sec. 35, at about the same altitude, and on Sec. 20, Huron, is at a

This sandstone disappears before we come to the south line of Sec. 28, though it is 8 feet high about a quarter of a mile north of the line. Continuing south we soon encounter another sandstone, which we might at first take for a higher bed, say the Port Austin sandstone, which can be traced by wells, etc., from Port Austin to outcrops on Sec. 3, Dwight, and thence close to the surface all the way to Robinson's Hill on Sec. 13, Dwight. But this is rather too far east, especially when we allow for some fifty feet difference in altitude, and moreover we seem to find the sandstone rising as we go up stream, appearing on the eastward turns of the stream, about 3 feet above the water at the south line of Sec. 32, Huron, and last visible in the west bank in Sec. 5, Bloomfield. While it is difficult to distinguish general structural dips from the minor undulations and cross-bedding prevalent through all this series, the appearance is to me certainly as if the Point aux Barques sandstone rose again. This may be one end of a gentle synclinal, of which we find the other end near Port Austin. We have accordingly made the lower boundary of the Marshall swing to the west here, and this brings it into line with the underground escarpment of rock which Gordon found, which in default of any better evidence we follow.[*]

He describes it as follows: "From a consideration of the well-records it is evident that a concealed rock escarpment representing the eastern limit of the Marshall occurs along a line approximately corresponding to the township line between Sand Beach and Sigel townships. At M. Cowper's, N. W. Cor. Sec. 19, Sand Beach, this sandstone comes within 6 feet of the surface, while R. A. Brown's well, 660 paces east and north, shows 48 feet to rock, which is a shale evidently belonging to the Coldwater shales. Again in Sec. 1, Paris, at Susalla's, the rock is but 6 feet below the surface, while a short distance, ten to fifteen rods, north of this the rock comes within 2 feet of the surface, and at Lock's farther south, it is but 12 feet to rock. Toward the east within about half a mile it is said wells fifty feet deep do not reach rock. In Sec. 12 of Sherman town-

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slightly greater altitude, we have a course of almost precisely two north to one west, or N. 27° W. With that strike the dip from Sec. 27, Port Austin, to Sec. 21 will be (58-18) about 40 feet per mile. The dip from Grindstone City to Port Austin as derived from the wells is (1160-1010 or 1225-1080) i. e., 150 to 145 feet in 5.5 miles, or 27 feet per mile while that from Grindstone City to New River is (1010-900 or 1080-1000 or 1029) more than 47 feet per mile. In the same way, comparing the top of Huron City hill with the sandstones apparently corresponding in Willow Creek, we have (104-20) + 2 = 42 feet per mile. The flattening of the dip as we approach the Port Austin synclinal seems evident.

[*] This escarpment is cut and exposed by Allen Creek in Sec. 25, Sigel, T. 16 N., R. 14 E., about 400 paces N., and 400 paces W. of the southeast corner and is apparently close to the bed of the stream for 100 steps.

ship, at Hoeldke's it is 54 feet to rock. At Parisville it is 90 feet. Wells to rock are not numerous enough to trace the line accurately, but the line drawn on the map approximately represents this concealed escarpment. No indication of this ledge appears in the surface configuration. East of Ruth no wells are found that reach rock. Several wells occur toward the south and west. Those to the southwest show that the eastern limit of the sandstone found at Susalla's, northwest of Ruth, passes to the southward of the latter place, crossing the county line into Sanilac county near the southeast corner of Sec. 31, T. 15 N., R. 15 E."

If we could see this escarpment, we should probably find that like many escarpments it was cut into by little streams that have crossed and cut it back. This might not be so if it were a single bed of sandstone with softer beds on top. It might then be the divide all the way and run with comparative regularity. But we know that to the west are the heavier sandstones of the Upper Marshall which would therefore be the main divide. For a mile or so west of this line, therefore, one is not sure of finding good sandstone water, but the chances are better the farther west of the line one is and the sooner rock is reached, while if the rock is deep, as in the wells on Secs. 20, 26 and 16, Paris township, the chances for good water are poorer.

As we have remarked, and as the map (Pl. VII) shows, there are enough outcrops of the three lower sandstones, the grindstone quarry, the Point aux Barques and the Port Austin, to start them off from the shore and it is not difficult to break up the Badaxe record as we have done into a series of heavy sandstones above the Upper Marshall, and then a triple sandstone series above the bottom in shales, but it may be that the parallelism thus suggested between this triple sandstone and the three sandstones at the north end of the county is purely fanciful, except in the steadily decreasing proportion of sand in the lower part of the series.

If we do assume such a parallelism then in the Badaxe well the Lower Marshall has already shrunk from 260 feet to 177 feet. Some shrinking we should expect, as the beds at the north end of the county show unmistakably in their beachworn fragments that they were immediately adjacent to the shore.

The fossiliferous series on Sec. 35, Port Austin, T. 19 N., R. 13 E., the Marshall *par excellence*, palæontologically speaking, can be traced down into Sec. 2, Hume, and the isolated outcrop, Sp. No. 19100, which is found on Sec. 10, Hume, at Port Crescent, seems to belong in the same series. The sandstone of Hat Point can be followed some distance south-southeast from the shore in bluffs in Sec. 7, and reappears in Sec. 20, Hume [Sps. Nos. 19096, 19097] thus giving us a good strike similar to that around Point aux Barques, but more to the north [N. 15° W.] The escarpment fronts east and all the indications are that the dip is the normal one to the southwest. But it is obvious that if the marked easterly dips which we had around Hardwood Point were long continued, we should have the Port Austin sandstone, which ran below the water line at Flat Rock reappearing from the waves. As already suggested, there is probably a little fault, enough only to counterbalance the abnormal dips in part, for we find the Port Crescent well only 25 feet deeper than those at Port Austin. The dip from Port Crescent to Caseville is, according to the wells, about (1750-1250÷11.7) 43 feet per mile on an average. This dip is probably a little steeper than that for the middle of the distance.*

Allowing for 40 feet dip or less and a strike not more north than N. 15° W., we find that the Hat Point sandstone should extend to Filion, and in confirmation we find on Sec. 20, Lincoln, a well with abundant water immediately at the top of the rock. It should again appear at the top of the Badaxe well on Sec. 19, Verona, and we find the first hundred feet of rock of that well and the wells on Sec. 24, Colfax, mainly sandstone, so that we should find the bottom of the Upper Marshall according as we use the dip derived from Harbor Beach, or a dip of 40 feet to the mile, some 2½ or 3 miles to the east of Badaxe.

Thus we find it continuing into a ridge in the rock surface, which extends on toward Tyre, a ridge which underlies the higher part of the county, though the rock surface is not anywhere near so irregular as the present surface, since wells upon the ridges of till strike the rock deeper down than those in the valleys. And finally just outside the county we find outcrops of sandstone once more, near Tyre where the old channel between the lakes around the Point has scoured down to rock. But to get the most close parallel to these Tyre outcrops, we must retrace our steps, and begin at Little Oak Point where, exposed in the Babbitt sandstone quarry and not at present worked, we have a coarse and porous sandstone. There is also sandstone on the south shore of Rush Lake, and we can trace the sandstone along, very near the surface in Sec. 6, Meade, exposed on the Pinnebog in Sec. 5 adjacent, extensively exposed along the road in the ditch on the north line of Sec. 16, Meade, and making a marked ridge which runs southeast through Sec. 15, Meade. The samples taken here are extremely like those from the Babbitt sandstone quarry. (Sps. No. 19101 and 19102 like Sp. No. 19161.) These sandstones are evidently near the center of the Napoleon sandstone and the summit of the prominent ridge in the rock surface. Hence we may obtain from it some idea of the general course of the strike which evidently veers from southeast to south. We do not know just how far this sandstone horizon lies below the top of the Napoleon sandstone but wells like Sovereign's on Sec. 30, Lake, Lounsberry's on Sec. 3, Chandler and the Badaxe cemetery well on Sec. 24, Colfax, make it obvious that there is a considerable thickness of sandstone and nothing of importance but sandstone between it and the top of the Napoleon. This latter we assume to be near Oak Point where the coarse water-bearing sandstones are overlain by bluish drab-colored limestone ledges of dolomitic or partly arenaceous character, fossiliferous, as described by Rominger (Vol. III, pp. 70, 103), and apparently similar in character to outcrops found on Secs. 18 and 19, Meade (T. 17 N., R. 12 E.). This line seems to be a well defined one in almost all the wells, being generally the one where a flow of water, or a new flow of water was struck. The Napoleon sandstone is much more porous than the overlying beds of the Michigan series. (Cf. Table II.) Tracing the top as best we can in the records of the wells, we have platted the observations in Fig. 6 and sketched in contours accordingly. The numbers of this map are of practical importance, for by subtracting the nearest one from the altitude of any point above tide, as given in Plate VIII one may form an estimate as to how far drilling should be carried for the best results. It will be noticed that the surface of the top of the Marshall as thus delineated is not accordant with, and is much more irregular than, the bottom of the formation in dip and strike. It is thrown into a series of gentle folds pitching toward the northwest and corresponding in a general way to that slight fold which we have spoken of near Port Austin and also to the fold in the coal mine at Sebewaing. As there may be some hesitation in admitting such a comparatively complex stratigraphy on the somewhat uncertain evidence of drill records, it may be well to mention some confirmatory facts:

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*From Sovereign's well, Sec. 30, Lake to Adams' well at Caseville at about equal elevation. the sandstone sinks from 87 feet to about 120 feet below surface. They are about 2.5 miles apart at right angles to the strike which would make a dip of only 21 feet per mile. Comparing Sovereign's well and Leipprandt's well, Sec. 13, T. 17 N., R. 10 E., we have similarly 228-27—(87-25) + 3.1 = 45 feet per mile.

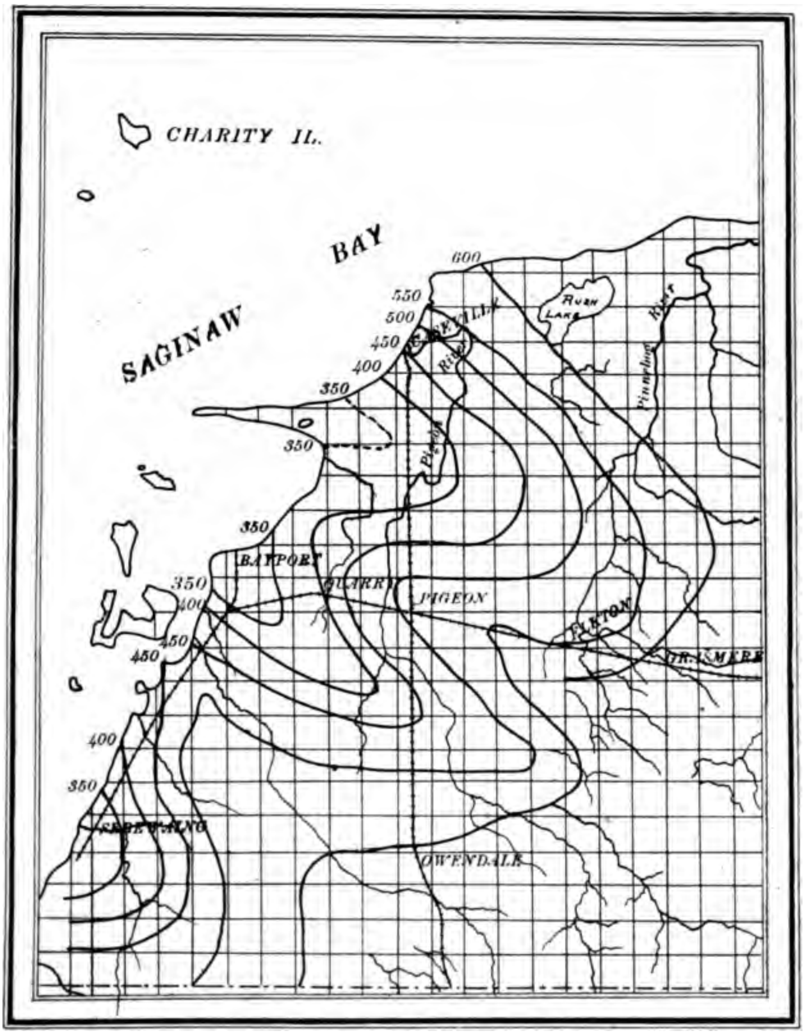

Fig. 6. Contours showing the elevation of the top of the Upper Marshall above sea level.

(1) The dips of the Bayport limestone on North Island, on Big Charity Island and at the quarries are, as indicated on Plate VII, in harmony with the structure assumed.

(2) At a nearly uniform distance above the top thus determined there is a gypsiferous zone, so that the deep rock wells in the area where the top of the Napoleon is less than 550 feet above tide, are pretty apt to be strongly mineralized. In fact the tracing of the gypsum had led me to some such stratigraphy long before the contours of Fig. 6 were drawn.

(3) The records of the Caseville and Bayport deep wells show that there is nowhere near the usual grade per mile between these wells.

(4) The old rock surface as given on Plate VII seems to show that the streams which cut it were adjusted to some such structure as here indicated.

§ 3. Lower Grand Rapids, Michigan series.[*]

In this the Lower Grand Rapids complex we have a series of considerable interest, both theoretically and practically, but one which taxes all the resources of the geologist to study, as outcrops are very rare. We refer to the series of dolomitic limestones, gypsum beds and shales, which we call the Michigan series. The harder beds of dolomitic limestone are the most likely to be left in ridges on the rock surface, and therefore the most likely to be exposed, and these bluish argillaceous limestones resemble very strongly those used near Milwaukee for the production of Milwaukee cement, which were also formed under similar geological conditions, though not at the same time.

The Marshall was, as we have remarked, a period of uplift and at least for the earlier part of the time a period of rapid degradation of the land, i. e., of wet climate. Toward the end of the time the climate may have become dryer, for the Napoleon is freer from mud, and more of the nature of a glass sand, with the grains of quartz well rounded and freed from foreign ingredients. I dwell upon this point because it has some bearing upon the coal question. Coal has been reported below the coal measures in a well on Sec. 2, Dwight, T. 18 N., R. 13 E.* and from the Michigan series in Sovereign's well on Sec. 30, Lake, T. 18 N., R. 11 E., also on Sec. 21, T. 15 N., R. 9 E. about 75 feet above the white sandstone of the Napoleon.

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[*] In Volume V, I included this series in the Grand Rapids, rejecting the term Michigan Salt Group as used by Winchell, because there are well founded and generally accepted objections to such terms as Salt Group, as applied to groups of rocks, and especially since we have in Michigan another formation much richer in salt, which material is, so far as yet known, merely a mineralogical curiosity in the "Michigan Salt Group." I then proposed to replace "Michigan Salt" by "Grand Rapids," a place identified with the manufacture of plaster from gypsum, so characteristic of this formation, including also in this term the limestones which were according to Winchell and Rominger equivalent. But I have on farther consideration decided that I ought to have retained the part of Winchell's name which was open to no objection, viz.: Michigan, and especially because during the formation of the series in question Michigan was a separate province to which these rocks were confined. I used the term Grand Rapids group in a more inclusive sense than the "Michigan Salt Group" of Winchell to include also the overlying "Carboniferous limestone" of Winchell, the Bayport or Maxville limestone of this report, which has also been well exposed at Grand Rapids. Since that time, however, the records at Alma and Midland and South Saginaw (Salina) with the samples preserved, together with the older records recorded in Vol. V, have shown that the gypsum beds and the characteristic shales associated are widely persistent and need not be confounded in one group with the limestone above, and at the time of formation of this group Michigan was a separate geological province, through which these rocks were quite uniformly developed in the basin in which they were formed. Their correlation with the Burlington and Keokuk, i. e., Augusta limestones of the Mississippi I have already mentioned (Chapter II, § 4).

While the Marshall very frequently contains coaly bits and fossil rushes, it has never been found to contain workable deposits of coal, and though the conditions during the time of the Marshall and the Michigan were in one way favorable, for the upper part was just about water level and small coal pockets prophetic of the genuine coal measures will probably be found in them, the probabilities are against finding workable coal in the Michigan series. For one thing, the abundant vegetation required to make coal beds requires a moist climate. On the other hand the accumulation of gypsum requires a reasonably dry climate, and we are not therefore likely to find much coal immediately associated with gypsum in the Michigan series. The coal reported from the Michigan series is likely therefore to be slight in quantity, and in most cases reported is likely to turn out black shale.

The conditions of formation of this series seem to have been as follows: The uplift of the Marshall had proceeded so far that not only Canada to the north, but northern Ohio and southern Michigan were out of water, and in the enclosed basin, thus formed, no extensive river entered, capable of keeping up the supply of water against the evaporation of a hot sun. The deposits must have been slow compared with those of the Marshall preceding. Limestone might be directly precipitated, and in that case would be likely to be free from magnesia, or the lime might be deposited in the shells of the animals. Fine mud would slowly form, and one of the most characteristic features of this formation are the beds of exceedingly fine clay, often quite plastic. It is likely that some of these will be valuable, if easily accessible. Finally after a sufficient time to allow of the concentration of the sea-water gypsum was deposited. This would be interrupted of course by variations in the wetness and dryness of seasons, and the cycle above mentioned was repeated with variations until a depression let in the waters of the open sea once more.

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*Cf. Winchell's Report, 1860, p. 74.

Just below water level at Oak Point are loose fossiliferous slabs of argillaceous limestone which might well be a good hydraulic cement rock. The limestone near Oak Point we lose sight of upon the surface* unless the limestones around Soule are of the same horizon. But the Soule limestones seem to be about 70 feet above the bottom, somewhat higher in the series, and are underlain by quite a thickness of dark blue shale, often reported as black, or even as coal,† before we come to the Napoleon. We find limestones extensively exposed on Sec. 24, T. 17 N., R. 11 E. and on Sec. 19, T. 17 N., R. 12 E., along the valley of the Pinnebog, and they seem to come close to the surface at a considerably greater altitude on Sec. 18, T. 17 N., R. 12 E. (Specimens Nos. 19103-5, 19009, 19222-23.) Then as the formation swings around in a synclinal following the contour curves of the Napoleon (Fig. 6), we lose sight of these limestone beds, though they are suggested by the record of Klemmer's well, Sec. 7, Colfax and some of the wells in Grant township, until we get down into Tuscola county, where similar beds are exposed above and below Cass City.

The shales with which they are associated are sometimes reported as black, but all the samples seen show only dark blue shales. Like the limestone, however, they are more or less pyritiferous. They are around Sebewaing often very fine grained and sticky, but vary somewhat in physical character from point to point.

Not far above the Soule limestones, near Soule, about 100 feet above the bottom of the formation is a gypsum bed, which grows less and less to the southwest. We may infer this position from the facts reported that gypsum was dredged from the river at Caseville and found in shallow wells and was first encountered in Codey's well in Sec. 24, T. 17 N., R. 11 E., and in shallow wells on Sec. 25, immediately south, whereas in Collison's well, Sec. 15, Fairhaven, the gypsum is probably not so far above the Napoleon sandstone, and in Bauer's well, Sec. 8, Sebewaing, I can find no trace of it, the whole thickness of the formation having dwindled from about 200 feet to 125 feet. Supposing it to be a hundred feet above the Napoleon, and that is about the relative position at Alma and Midland, we may trace its outcrop on the rock surface of Plate VII, by seeing where a surface 100 feet above the surface outlined by the contours on Fig. 6, would cut the surface indicated by the contours of that plate. For example, the surface of the Napoleon is about 500 feet above tide near the southeast corner, Sec. 5, T. 17 N., R. 11 E. and hence the gypsum bed should be about 600 feet above tide there. But the rock surface, cf. Plate VII, is also about 600 feet above tide. Hence the gypsum should strike the rock surface there. Thus we can follow point by point the extension of the gypsum bed. We may control and check this somewhat theoretical location by observations upon the character of the well water. For not only is gypsum somewhat soluble, so as to strongly impregnate the well water of any well which strikes it, but the evaporation went on so far as in some cases probably to throw down a little salt, for from only 100 feet depth Mr. Leipprandt on Sec. 13, T. 17 N., R. 10 E., gets a very strong brine. If rock salt was not formed, the sea water must have been at any rate a concentrated brine, which would be more or less entangled in the pores of the rocks laid down. Hence wells drawing water from this formation, would be strong of sulphates (gypsum is sulphate of lime) and very probably salty.

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*Although it is not uncommon to find a limestone just above the Napoleon sandstone in the wells, e. g., Bauer's well on Sec. 8 Sebewaing, and Haffner's well on Sec. 34, Fairhaven, T. 16 N., R. 9 E.

†Sovereign's well on Sec. 30 Lake.

Now we have, to confirm our line of farthest extension of gypsum as drawn upon Plate VII, the following facts:

In Caseville Harbor it appears to have been dredged, and at Mintline's place near by, it is reported to have been struck. To the southeast on Sec. 1, T. 17 N., R. 10 E., Adams' well found salty water at 93 feet depth which was removed by casing to 112 feet. Over on Sec. 2, Libby and Gardner both have wells strong of sulphates, and to the east on Sec. 6, Chandler, near the east line there is a salt spring and Woodworth's well near by on Sec. 5 is quite brackish. In Sec. 8 and also on the north side of Sec. 9 we find wells strong of sulphates, but not so salty (perhaps the salt bed thins out as we approach the edge of the basin).

On Secs. 16, 17, 18, we have wells charged with sulphates. To the east of these sections we have a very different water, very free from mineral matter, and there are no signs of the gypsum, except that on Dufty's place there is a sinkhole which might suggest gypsum. This, however, probably comes from the collapse of some cave in the limestones beneath the gypsum. On Sec. 24 we find in the south part wells and reports which indicate gypsum, and most markedly so in the next section south, Sec. 25. On Sec. 36 we still find records and waters that indicate gypsum, and even over on the southwest corner of Sec. 6, Colfax, then the line of gypsum extension swings north, the Elkton wells not being strongly mineralized, and follows near the north line of Oliver township.

As it advances into Caseville the gypsum seems to be cut into by the old river valley. Otherwise it would cover practically all this corner of the township, though the anticlinal indicated in the Napoleon sandstone by Fig. 6 would carry it clear of Berne.

Then apparently it follows down the old river valley which is quite natural as it would easily be dissolved and eroded, but finally extends over it, as we find highly mineralized wells on Sec. 23, and at Winsor, and finally one on Sec. 10 near Owendale, which only penetrates a short distance into the rock. From a well on Sec. 33, Oliver, a foot of plaster is also reported, but none of the waters in that region indicate any such extension. In fact as to the extension in Sec. 23 and Winsor, it must be remembered that it is by no means necessary that wells strong in sulphates should have their sulphates derived from gypsum, or from sea-water at all. Sulphates may be derived from the oxidation of sulphides of iron pyrites, etc., which are abundant in the rocks of this and the over and underlying series. Hence sulphated water can be used readily only as confirmatory of evidence which in the direction of Owendale is scanty. But turning northward again as is required by the anticlinal indicated by Fig. 6, in the Napoleon, we find in Secs. 28, 29, 30, and in the north part of Secs. 31, 32 and 33, Winsor, T. 16 N., R. 10 E., a group of wells very strong in sulphates and cathartic. This group we can trace on through Secs. 25 and 26, Fairhaven, and here we are quite near to Collison's well on Sec. 16, from which we have seen samples of gypsum. This well is in the midst of a group of wells which all are heavily charged with sulphates.

Over on the southwest side of the anticlinal which runs up here (indicated by the rise in the Napoleon in Fig. 6), in the Sebewaing coal basin, the gypsum does not seem to have been formed, judging from the well records and samples, and hence we have extended this line no farther in that direction. The Michigan series as a whole still occurs, with characteristic, fine, plastic, blue or gray shales, and dark blue or brown, pyritiferous dolomites, and the wells which pass through it are liable to be rather heavily charged with sulphates and salt. The most detailed and accurate record is that of Bauer's well in Sebewaing, Ch. V, §6. The fact that the gypsum does not extend here may be explained by supposing that at the time of the gypsum formation the sea had dried so much as to have shrunk away from this part.

In some parts of the basin at least there are probably other beds of gypsum above this lowest which we have just followed. Such are indicated by the salt spring charged with sulphates on Sec. 16, Caseville, and by the fact that Leipprandt who makes salt from a well 100 feet deep on Sec. 13, Caseville, also has a well strong in sulphates only 55 feet deep. Schubach's well on Sec. 23, and Lutson's on Sec. 32, Caseville, and a well on Sec. 4, Winsor, all seem to point to a higher bed somewhere about 175 feet above the Napoleon. According to F. Mueller a gypsum bed was struck in wells on Sec. 3, Winsor, and large specimens of a good quality of gypsum were shown me. It was said to have been met about 32 feet down. If in place, which I doubt, it must be at almost the extreme margin. Wells near by show a much greater depth to rock, however, and the gypsum seen may have come from the drift, like blocks of gypsum found on digging a well in Sec. 26, Caseville, T. 17 N., R. 10 E. The upper part of this formation is shown in the deepest well on Sec. 5, Winsor, and is a fine grey shale, somewhat calcareous, with narrow seams of sand, and somewhat pyritic, but in general very fine grained. These upper shales are apparently lighter colored in the northern part of the county than the shales in the lower part of the series. Near Sebewaing no such contrast can be observed.

Concerning the fossils of this formation, see Chapter X.

§ 4. Bayport (Maxville) limestone.

This is one of the best exposed and most fossiliferous of the formations of Huron county. It is the only characteristic representative of the great series of limestones of the Mississippi valley. As I have mentioned in my account of the geological column, in Chapter II, it represents the Maxville limestone of Ohio, and the Upper St. Louis limestone of the Missouri Survey, and probably marks the epoch of depression which admitted the open sea once more into the basin of Michigan (Fig. 2), and put an end to the separation of that basin into a distinct province by itself that characterized the epoch of the Michigan series. The deposition of gypsum might have been terminated in two ways,—either by an increase in the precipitation and supply of fresh water, or by an opening to the sea. The characters of the Bayport deposits, clear limestones and dolomite, and limestones, and white sandstones, crowded with life, and yet comparatively free from mud, indicate that the climate remained dry,—that it was not the former alternative but the latter that took place. This formation is characteristically full of chert, chalcedonic and clay nodules, often a genuine limestone, about 95% $CaCO_3$ with little magnesia but generally impregnated with silica, and it abounds in corals, which generally prefer clear water. Signs of vegetation are rare. From all this we may infer that at this time the climate continued dry and hot as in the previous epoch, but that the Michigan basin became an arm of the great interior sea. The thickness of this formation around Bayport is about fifty feet and the indications are that there is a considerable thickness all along that edge of the basin, but as we go southwest it seems to diminish considerably in thickness, until around Sebewaing we cannot safely assign more than 27 feet to this formation. Brown, yellow and white, not blue nor black, are the more characteristic colors for this formation. On Charity Island the formation is quite well exposed, and has been described both by Winchell and Rominger. Winchell gives the section on the north side of the island as follows:* C. Limestone, areno-calcareous, containing Bryozoa, Cyathophyllidæ, and Allorisma 10 inches. B. Limestone with cherty nodules 10 inches. A. Sandstone, calcareous, obliquely laminated 4 feet. "Some portions of A are well characterized sandstone of a whitish or grayish color. The laminæ extend from top to bottom of the mass, dipping northwest at an angle of about 45°. They are quite undulating and even contorted, and the whole mass shows something of a rude concretionary structure." This cross-bedding of the sandstone is like that met with in a sandstone in similar relation to the limestones on the Bayport quarry on Sec. 5, T. 16 N., R. 10 E., at a depth of from 25 1-3 feet to 29 feet [Fig. 9]. It also reminds one of the abnormal dip of the lamination in the type exposure of Winchell's Parma sandstone (Report, 1860, p. 113). The "rudely concretionary structure" is evidently the same as the anticlinal of Rominger's description (Vol. III, p. 119), who describes the section as follows: Upper horizontal beds, a pure lime rock, free of sands, with numerous flint nodules, and interlaminated with thin seams of calcareous shale with *Lithostrotion proliferum*, *Syringopora ramulosa*, *Fenestella*, *Polypora*, *Productus flemmingii*, *Allorisma clavata*, and fish teeth not abundant, 8 feet. Lower beds lying in a discordant stratification beneath the upper in an anticlinal, the higher ledges arenaceous but with lime prevailing, with flint concretions, *Zaphrentis spinulosa*, *Lithostrotion proliferum*, ripple-marked, 5 feet. Lowest beds a light colored ripple-marked calcareous sand rock about one foot above the water level, 1 foot. Rominger sketches this as follows (Fig. 7), and found no outcrops elsewhere on the west side of the island.

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*Report, 1860, p. 102.

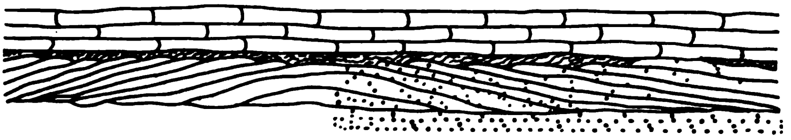

Fig. 7. Illustration of section on Big Charity Island, after Rominger, Vol. III, p. 119, showing discordance in the Bayport limestone. Completed so as to show the lower bands as we observed them, in dots.

Prof. Davis and I visited the island, making farther collections. We added to the above lists a form much like *Athyris trinucleus*. The fauna is in general identical with that of Wild Fowl Bay. The islands had changed considerably from the form given on the Lake Survey chart and there was a long spit northwest from the lighthouse, more as in the outline on the old Walling atlas after the Land Office Survey. There has been considerable growth also toward Little Charity, a broad stretch being left bare, and between the two a small island known as Gull Island was just laid bare.

The point to the north is made up of gravel and boulders, but a short distance southeast of the lighthouse, the outcrops of characteristic layers of limestone with abundant Lithostrotion, chert nodules, and Phillipsia pygidia, begin. On the first little point from the lighthouse in this direction there are 6 feet of bluish shaly limestone with abundant Allorisma, in nodules and geodes, Lithostrotion, etc. (Sp. 19178-19186). About 50 steps farther southeast we find close to the water's edge a three inch bed of hard ringing flaggy gray limestone (Sp. 19187) undulating somewhat, but apparently under the Lithostrotion beds and dipping gently southwest. On top of this bed, *and thus replacing the limestone*, we find an almost pure white sandstone, cross-bedded strongly with a dip to north of west in the cross-bedding (Sp. 19188). About ten steps on in the lower part of the sandstone are large Allorismas (Sp. 19139). Flinty and cherty limestone layers, over-and underlain by sandy ones, continue near the coast to the east point. The bay opening southeast is sandy, but on the long point to the south we find flat outcrops in the broad zone left by the recent water retreat. They frequently contain calcite geodes and weather yellowish brown (19192-19202). They are sparsely fossiliferous, the most interesting form being one that resembles *Athyris subquadrata*, but there are also fragments of Productus, Lithostrotion, Bellerophon?, etc. On the coast facing Little Charity Island there are low paving-slab outcrops of brown brittle dolomite with cavities, and the surface is strewn with chalcedony and other geodes, which have evidently been left by solution of the limestone that enclosed them, as the irregular surface has not been rounded by erosion (19190-19191).

Though, as I have said, the dip appears to be to the southwest, these beds on the southwest side of the island appear more like some of those low down in the section around Bayport. But on the other hand the sandstone there comes under the "firestone" dolomite which most resembles the brown brittle dolomite aforesaid. But as there are undoubtedly alternations and rapid variations in the section, the dip of the strata here can not be regarded as free from doubt. The probability of a southwest dip is strengthened by what Winchell described on Little Charity Island, which he says has similar outcrops, with Syringopora, chert concretions, Bryozoa, and Cyathophyllidæ (i. e. Lithostrotion). He also remarks that the rock may be seen under water for a long distance southwest. The charts indicate rocky bottom and shoal water for some two miles and a half in that direction, while to the northeast of Charity Island the descent to deep water is sharper. Taking the above facts into consideration with the rock exposures along the shore of Arenac county we cannot but think that a rock ridge extends across the mouth of Saginaw Bay, following the beds of this formation, which are relatively resistant to erosion.

According to the contours of Fig. 6, the limestone should appear under Sand Point and it may do so, but I know of no wells nor outcrops that settle the question. We find it next on North Island off Wild Fowl Bay, but there the dip appears to be northeasterly, while at the Bayport quarries and around Bayport it is similar to that on Charity Islands, so that it seems as if North Island might be on the west side of a long, narrow much eroded synclinal running north, and if so it would be the more likely that, if not eroded away (i. e., if the rock is not far below the present surface), we should find the other side of the synclinal under Sand Point. This would be of interest because this formation yields excellent water, and often flowing wells. A well on the end of Sand Point a hundred feet deep would amply test the question for this formation. If this limestone was not found the next thing would be to go down about 300 feet, case off the overlying flows and take water from the Marshall.

On North Island a quarry has been opened and deserted. In it the Lithostrotion, and chert nodules, and carbonates are abundant, and a large Bellerophon occurs like that found by Whitfield in the Maxville limestone* (Sps. 19208-19211). This quarry is on the north side of the island. As we go northeast we find similar strata continued out under the water, with trilobite pygidia, etc., and Allorisma (Sps. 19212-19216). As we go southeast along the shore 100 steps to the cove on the north side of the island, we come to a layer rich in Lithostrotion, which seems to overlie the beds just mentioned, as in the Bayport quarries, and dip gently to the northeast.

Going toward the north end of the island we find that the retreat of the waters had connected it by a goose neck ridge with the small outlying rock of earlier maps, and we come to a dark brown dolomite, ferruginous and not fossiliferous (at least abundantly). The south shore of the island shows a somewhat fossiliferous limestone with Bryozoa, limestone and corals.

Between this island and Heistermann's (Ching-qau-ka, or Stony) next south, the water is very shoal, and according to the Coast Survey charts there is rock almost all the way, and the north end of Heistermann's Island shows thin bedded limestone alternating with sand layers, which would seem to represent lower layers of the Bayport quarry. Some of the layers become on weathering at least, a well marked sandstone. The outcrops are not more than five feet above water, and Winchell speaks of them as much brecciated, a character which I failed to note.

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*Ohio Geol. Sur., Vol. VII, p. 479.

On the north side of North Island the limestone drops off in quite a steep bluff but to the southeast between the islands and the shore, it is probably not far from the surface, judging from the shingle, and we find it reappearing again in a low outcrop with characteristic Lithostrotion and Allorisma and other fossils on the main land along the west line of Sec. 36, T. 17 N., R. 9 E. (Sps. 19170-19173). Similar beds with similar fossils we find again at the top of the quarry on Sec. 5, Winsor. Returning to the main land we strike under Bayport village, however, sandstones such are more common in the lower part of the formation, and the beds outcropping, for example, just to the west of the railroad pier, are of a dark flinty dolomite character, and seem also to be lower down.

As we go along shore to the east, the bluffs, now mainly grassed over, seem to be rising, but the dip of the strata to be gently to the west. In other words we have crossed the axis of the synclinal or basin, the uppermost layers exposed being the limestones rich in Lithostrotion. Winchell says, however, that the dip is very slight to the southeast. He makes the following section:

F. Limestone argillaceous, cherty, perforated extensively by a Syringopora, 10 inches.

E. Limestone, compact, bluish, weathering white, 1 foot.

D. Limestone arenaceous, with nodules of chert. Seen dipping into the water 10 rods west. (True, but how does he reconcile this with a southeast dip?)

C. Limestone, dark calcareous, with bituminous (flinty?) streaks and laminae, intersected by broad cracks which have been subsequently filled with material like D, 10 inches.

B. Limestone, yellowish, highly arenaceous, thin-bedded, rather incoherent, the lower one-fourth curiously banded with lighter and darker streaks, 1½ feet.

A. Limestone, arenaceous, highly shattered and recemented. "The flint nodules in the layer D, are bluish, of a fine homogeneous structure and strike fire with steel, with great readiness. They exist in large quantity." The layer E. he recommends for building, and D, E, and F, for making lime. This whole section with the exception perhaps of part of A., for the difference between calcareous sandstone and arenaceous limestone is neither great nor persistent, is in the "firestone" belt of the exploratory borings given among the well records of Secs. 35 and 36, and must cover somewhere from 10 to 16 feet of the quarry section.

Rominger gives a more complete section, as follows: (Geol. Sur. Mich. III, p. 120.)

1. Light colored arenaceous limestones with an alternation of purer calcareous and prevalently sandy seams with many fossils—*Zaphrentis spinulosa*, *Lithostrotion proliferum*, *Syringopora ramulosa*, various forms of Fenestella, Polypora, etc., Productus, *Allorisma clavata*, and fish teeth (Cladodus, Helodus), 10 feet.
2. Dark gray limestone of smooth conchoidal fracture, pervaded by syringopora-like flexuose, anastomosing channels, 1 foot.
3. Similar dark gray limestone of smooth conchoidal fracture, 1 foot.
4. Another similar bed, 1 foot.
5. Blackish thinly laminated calcareous shale, full of scales, teeth, and bones of small fishes, beside a species of Cypris or Cythere, 2 feet.
6. Dark gray bituminous limestone with smooth fracture, 8 in.
7. Arenaceous limestone laminated, 2 feet.
8. Sand rock, few in.
9. Delicately laminated limestone, 6 in.
10. Shale, seam.
11. Gray limestone with cherty nodules, 1 foot.
12. Greenish white calcareous sandrock, 5+ft.

Total, about 25 feet.

Comparing this with exploratory section No. 3, on Sec. 36, T. 17 N., R. 9 E., we can identify the bottom bed 12, with the sandstone of the same and beds 7 to 11 probably with the 3 2-3 feet of limestone; beds 2-6 may be the 4 1-4 feet "firestone," No. 2 being the bed from which our Sp. 18207 is taken—from outcrops near the picnic grounds west of the railroad. The upper ten feet correspond to the outcrops on the west line of Sec. 36, and the first three feet of the quarry, bed No. 1, Fig. 8. The next beds are the building stone beds of the quarry (No. 2 Rominger=F. of Winchell?) and the black shale seems to be represented in the quarry at 8 feet, 6 inches. (Compare Winchell's C.) Rominger's sandstone bed No. 8 may be parallel with the sandstone from 9 feet, 8 inches in Fig. 8. Rominger's beds 9 and 10—the "delicately laminated limerock and shale" —may represent the cement rock of the quarry section, cement rock being generally an argillaceous limestone, and we have as satisfactory a correlation, as can often be got. The dip of the limestone

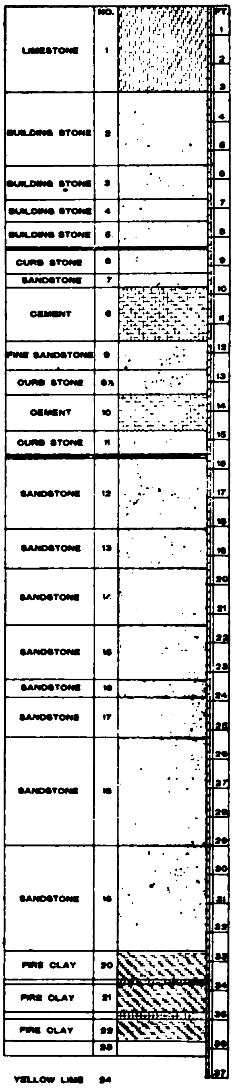

Fig. 8. Beds as given at Bayport quarries.

from hole No. 1 in the quarry to hole No. 4 on Sec. 35 is * about 12 feet to the mile, which is not far from that indicated by the contours in the underlying Napoleon sandstone in Fig. 6, for the same direction. The dip between holes No. 3 and No. 4 would be† 26 feet a mile, which would yield for the three points a dip to W. 39° S., of 27 feet per mile, but the position of the limestones on North Island and their dip forbid us from regarding this as a dip at all widespread and indeed it is not justifiable to join three points on a pitching synclinal to obtain a dip which can be expected to hold generally true. However, it shows plainly enough that the dip is really west and not east. The corresponding strike seems moreover to be almost exactly that of the limestone ridge from Sec. 5, Winsor, to Secs. 9 and 15, where the Lithostrotion beds lie at nearly the same altitude as on Sec. 5, and are very close to the surface. The limestone is exposed in a slabby pavement profusely strewn with weathered out Lithostrotion in the ditch on the north side of Sec. 5 and we find *Lithostrotion proliferum*, and also *mammillare* (=*canadense*) profusely strewn upon the fields in Sec. 9. The last place in this direction where the limestone lies near the surface is Sec. 22. All the way along it forms a pronounced ridge in the rock surface with bluffs facing an old river valley to the northeast. The sides of this river valley may be even more precipitous than our contour map indicates them, for such a massive cherty limestone overlying a formation of soft shales and gypsum, would be practically sure to outcrop along a river valley in an escarpment of vertical bluffs in which caves would be likely to form. And in fact we find in developing the quarries, and running the adjacent railroad spurs that the northeast wall of the limestone is nearly vertical so that the drop of the limestone is reported to be from 12 to 18 feet. Reports of cavities struck in this formation in sinking wells are also frequent. I happened to be standing by when one was struck in Bauer's well at Sebewaing.

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*Either (48.2 — 3)—11.16, i. e., 34, or (48.2 — 16)—(11.2 — 10.5) i. e. 32, or (48.2 — 36)—(11.2 — 34) i e. 35 feet in 2.78 miles.

†(20.43 — 8)—(11.16 — 10.5) i. e. 12 feet in 0.47.

Turning from the Bayport quarries to the southwest on the other hand, we find the limestone falling gently in this direction, according to the quarry authorities about 3 feet per hundred to the west, more than the dip above given, but that was an average taken very nearly to the center of the synclinal. In the quarry the bottom is now in the thinner bedded, bluer limestones and the bituminous shale parting shown in Fig. 8, at 8 feet 5 inches. The Lithostrotion occurs most abundantly above bed No. 1, and the quarry has developed about 3 feet of limestone above layer No. 1 of Fig. 8, which has been analyzed. (Chapter VII, § 7.)[*] The chert concretions which contain some clay are very often pear shaped, with a pit at one end, not infrequently enclose some shell, and are most abundant immediately below in layer No. 2. Fig. 8. In the lowest bituminous layers I observed a large ammonoid that I was not able to extract. The Producti are not altogether abundant, and are more often perhaps in the lower layers. The Allorismas sometimes occur in the chert concretions. The two valves are commonly together, but frequently flaring, showing the original presence of the ligament, and often not at all parallel to the bedding, in noteworthy contrast with the way the shells occur in the beach deposits of the Marshall.

As we have said, to the southwest the limestone slopes off gradually in sharp characteristic contrast to its behavior to the north and east, and the same contrast is noted on Sec. 9. Wells down to it, give an abundant supply of water, and as soon as the surface of the ground is below the level of the quarry we begin to get flowing wells (Fig. 9). The deepest part of the synclinal seems to be on Sec. 12, Fairhaven, and then the limestone rises to appear again at the surface on Sec. 14, where it is exposed in a slabby pavement in the valley of the Shebeon, and the ditch on the north line of the section. Mr. W. H. Wallace, formerly Superintendent of the quarries, thinks that through Sec. 14 goes a fault, as he finds limestone to the west of the line of the supposed fault, and sandstone to the east. Such a fault is not in itself unlikely as we have one of the same character in the Sebewaing coal mines, in similar relation to a synclinal, but in view of the way that sandstone replaces limestone in this formation I cannot consider the evidence conclusive, and at any rate such a fault has no great throw. Were there such a fault, however, it might be of importance in concentrating lead ore, but as yet the explorations have shown no concentration.

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[*] Accordingly Benedict in "Stone" Aug. 1898, p. 154, calls No. 1, of Fig. 8, ledge 2.

The calcareous sandstone here exposed is very fossiliferous, and has been noted by previous writers. It should be studied by an able palæontologist on the spot, as it is often very friable, even when charged with fossils. Beside previous forms is one described as *Spirifera Keokuk*, which appears to me to be more likely a Spiriferina. For a fuller list see Chapter X, § 4. These beds must be in the lower part of the formation, for the wells after passing from the calcareous sandstone, which is the surface rock, into a more massive limestone, which has been developed by some test pits below, in about 12 feet pass into a "blue rock," which appears to belong to the Michigan series, and to be a pyritiferous shale. South of this exposure the limestone is absent for some distance, being lifted up by the anticlinal indicated in Fig. 6, and the depth to rock is greater, but if we may trust the Lake Survey charts, there is a rock bottom almost all along the coast, and in that case the limestone ridge or bluff probably turns to the south almost at the coast line and following it along returns again, as indicated on the map, somewhere north of Sebewaing, to the land.* In its return,

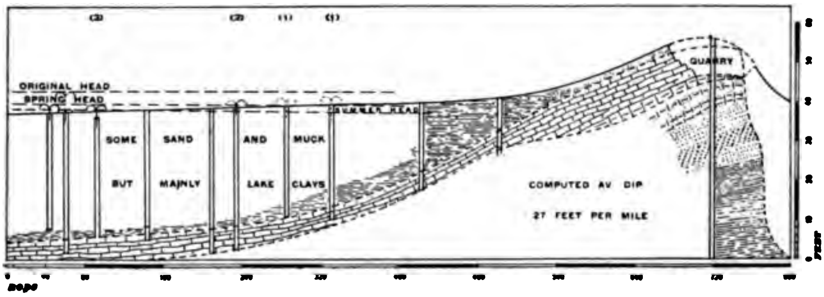

Fig. 9. Cross-section from Bayport quarries, southwest showing the relations of present surface, rock surface, flowing wells, and varying water level at point of intake.

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*Between Haffner's in Fairhaven and Sebewaing, is 2⅔ miles. Difference of elevation of Napoleon sandstone is (610 − 132) = 478 − (596 − 252) = 344, i. e. 134 feet; accordingly the dip is 50 feet per mile. Hence the limestone bottom 127 feet down at Sebewaing (596 — 127), 469 feet above tide, will strike the rock surface 540 feet above tide about 1.42 miles north-northeast of Sebewaing.

however, it is much thinner, as shown by the record in Bauer's well in Sebewaing, and in some of the well records in this corner of the county cannot be recognized at all.

§ 5. Coal measures.

The Coal measures occur only in a little basin near Sebewaing. This formation does not anywhere outcrop, and we are therefore dependent entirely on the well records and the shafts for our information. I am obliged to the courtesy of Mr. Chappell for an opportunity to visit the mine of the Sebewaing Coal company. As litigation was in prospect, our notes are in some ways deficient and wanting in numerical accuracy. The following sketch-map (Fig. 10) and section Fig. 11, show the general relations. The two companies to first mine the coal both began in troughs. The main shaft of the Sebewaing Coal company has about 4½ feet of coal at a depth of 125 feet. At the air shaft, 200 feet west, the coal is but 109 feet deep, and at the first shaft which was opened (still farther east), by John T. Russell, it was but 86 feet down through the coal. In this first mine there was much water. One miner* reports having encountered a water channel into which he could stick his whole head, and I myself saw such a channel in the present mine which would easily admit an arm. Turning from the 125 foot shaft to the west we find the coal rising, for the last fifty feet quite sharply, as much as one foot in six, until we come to a fault, which may be from 350 feet to 650 feet west of the shaft. On the line of the fault was this cavity which had a corroded surface, somewhat as if the water had made it by dissolving pyrite from the rock. This cavity is 8 inches by 5 inches and many feet in depth. Slickensides on the coal are well marked and also in the slate. Though the fault was always reported to me as having an upthrow west, it appeared at this point as having a downthrow of about 2 feet, the overlying slate coming in at the roof. The dip of the fault, judging both by the cavity and slickensides aforesaid, was steeply to the west.† The general relations along an east and west line are illustrated by Fig. 11.

I noticed little crystals of gypsum on the surfaces of the coal at this point and as we approach the fault the mine is very wet, and the mine water is somewhat salty, and very strong of sulphates,

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*Geo. N. Fleming.

†From the open cavity I should judge the dip to be about 80° or by slickensides 60° to 70°.

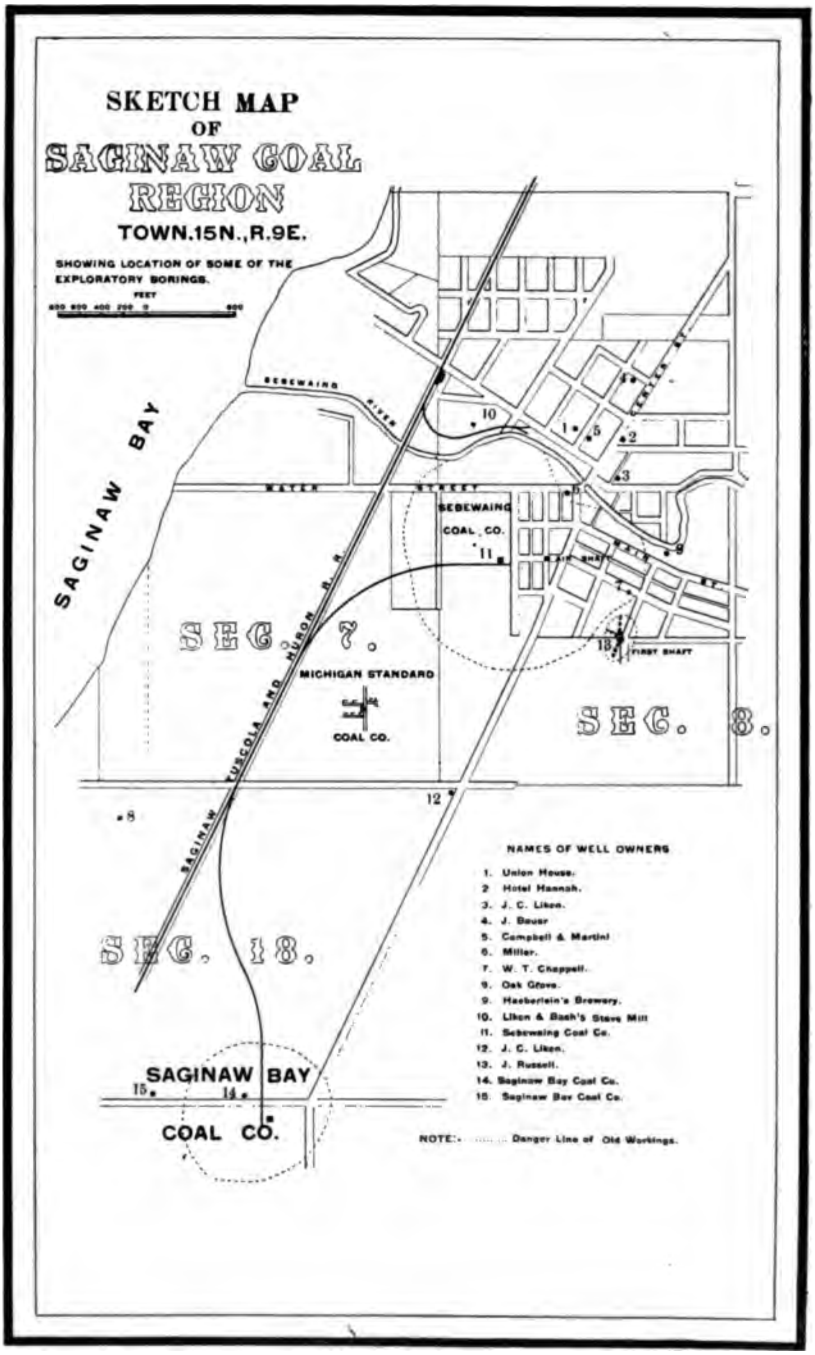

Fig. 10. Sketch map of Saginaw coal region, showing location of some of the exploratory borings. The mines have not been mapped, but the dotted line indicates the danger line or area within which the workings are probably confined.

depositing in the galleries a heavy flocculent precipitate of iron. The water is said and seems to come in from the bottom. It is true, however, in a general way, that the fault throws the formation up, i. e., that the coal to the west and southwest is higher than at the shaft, and as we often find in going toward the center of a coal basin another seam makes its appearance above the first. The section on Sec. 7 is about as follows:

Surface clay, with at times a few feet of bottom hardpan, 40-50 feet.

Sandstone, 15 feet or less.

Bluish shales passing at bottom into black shales and at bottom sometimes a 1-foot bed of coal, 6-13 feet.

Fireclay and lighter shales, 19-6 feet.

Lower coal, sometimes wanting, but often up to 4 feet.

"Fireclay," 0-5 feet.

Sandstone, 12 feet and more.

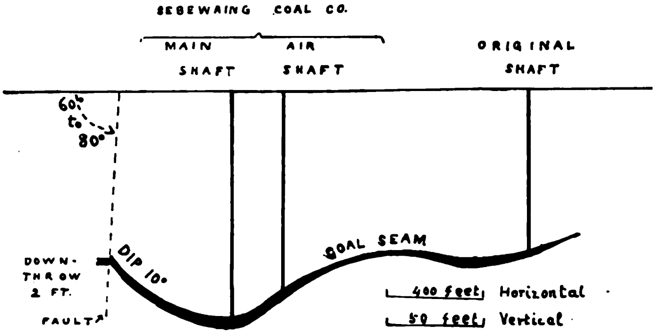

Fig. 11. Illustrating the relations of the coal and the fault at Sebewaing. This is a cross-section in a generally westerly direction, but the shafts and borings shown are not in line.

At the time the coal was formed the land was just about the level of the water, and in the marshes and flats thus formed the coal was deposited. It has been estimated that in the shrinkage from vegetable matter to coal, a loss of volume to about one-fifteenth takes place, so that a four foot bed of coal would mean an original swamp deposit some 60 feet thick. Thicker deposits would generally be formed in the hollows of the surface, and as they subsequently shrank and settled, there would be a tendency for faults to be formed toward the center of the basin and so in settling there might be a basin formed on top where in a subsequent overlying swamp another coal deposit might be formed. We find accordingly as we go from the fault to the south, that the little upper coal seam already mentioned appears. So in Sec. 18, while the section on the north part of Sec. 18, say in Liken's new deep well, is much like that already described, the beds become deeper in the south part of the section so that the lower coal is generally over 90 feet deep. The shaft of the Saginaw Bay Coal Company is said to have struck coal 4 feet thick at 110 feet below surface, and on the south line of the section it is also deep. There are some sudden variations in the recorded strata, however, due to the following cause. These old swamps, lying at or a little above the water level, were extremely likely to be cut through by old river channels, which would form sandstone beds, or they might also abut against old ridges of beach sand skirting the coast. Suppose for example that the present lake should now rise twenty feet. There is a strip of somewhat swampy country from Bayport southward which would again become a swamp. If the rise of water or lowering of the land was slow enough, the surface of the swamp might build up with vegetable matter fast enough to keep pace with it, making a thick bed of muck or peat. Now if the lake rose still farther the dune ridges and the whole country would be buried, and this bed of muck might become coal and might then appear as a bed of coal abutting against, or cut out by the bed of sandstone which would be formed by the ridges of sand upon which the "ridge roads" now run. The change from coal to sandstone would be quite sudden. And so for example we find that Mr. Liken's new well near the northeast corner of Sec. 18, T. 15 N., R. 9 E., only sixteen to thirty feet away from a previous exploration for coal, found a considerable bed of coal which was almost replaced in the older exploration by a thirty foot bed of sandstone. In Sec. 18 these sandstone channels or ridges seem to be prominent, as we find another encountered by the deep well put down by Russell, close to the Saginaw Bay Mine.

On Sec. 17 we find the coal also ranging from 106 to 80 feet in depth. The last doubtful report of coal comes from Sec. 21. Any farther extension in that direction would be cut off by the buried river valley, indicated in Plate VII, but as is indicated in Fig. 6 by the contours of the Napoleon sandstone, the basin probably is opening out and deepening to the west and in fact coal is reported from Fish Point and from Sec. 12 and Sec. 13, T. 16 N., R. 8 E., in considerable quantity and sometimes at greater depths than in Huron county. A tendency is noted, without exceptions, for the coal to be thicker where it is struck at greater depths, which may be explained by the thicker formation of the original muck in the hollows of the surface.

At the mine of the Sebewaing Coal Company the coal is from 4½ to 5 feet thick, about as follows:

4 inches "bone coal," i. e., lean coal that will burn, but without reducing in size, then

1 inch to 1½ inches of pyrite then

4 feet of fair coal somewhat pyritiferous.

There is a good slate roof, and fire clay underneath often in some cases pretty sandy. The bluish gray slate roof shows no fern impressions so far as seen, the only fossil noted being in the coal seam, and mainly small bits of rushes and vegetable matter, Lepidodendon and Calamites. One fragment of Stigmaria, changed largely to pyrite, was picked up by C. G. Maywood of Albion College, and Mrs. W. L. Webber has a similar specimen.

The coal contains at least 3% of pyrite, and the refuse piles effloresce with sulphate of iron, and take fire spontaneously.

CHAPTER VI.

WELLS AND BORINGS.

§ 1. Introduction, utility of the collection of records.

The main part of this chapter is composed of the descriptions as we have gathered them from well-drillers and owners, of the wells of the county, arranged systematically by township, range and section. It is possible that some one may say, "What is the use of this?" So far as the improvement and development of the water supply are concerned the use will be the subject of the next section. But it may be well also to call attention to the fact that without the data furnished by systematic inquiry concerning wells, such contour maps of the rock surface, or of the top of the Napoleon sandstone as given in Plate VII and Fig. 6, would be impossible. Without these maps we could have, from the few outcrops scattered over an almost plane surface, but very vague ideas as to the structure and distribution of the rocks below. And if any one should reply, why not give these maps then alone, and not the raw material, we make answer that in the maps the facts can not be distinguished from the theoretical deductions added, and are to a certain extent inaccurate. As we have seen, even the railroad levels do not agree among themselves, and so even Plate VIII showing the altitudes of the present surface of the county is liable to be in error as much as twenty feet, though we hope that the relative accuracy is generally greater (that is to say, although for example the level of Ubly should prove to be ten feet out, it would not effect the relative altitude of the hills and valleys around the town). But allowing that the contours of Plate VIII are liable to be 20 feet out, Plate VII and Fig. 6 which are constructed from them, and from the well records which are in parts of the county yet but few, must be still less accurate. Now, as new wells are bored and their records collected, if a more accurate contour map of the county is to be constructed with the aid of railroads or levels yet to be run, in this chapter are recorded all the data which we have toward better maps on the same lines. From our maps alone one cannot tell what part is more, what part less sure, what part observation, what part theory. To make this chapter thus a summary of recorded facts (facts which could not be collected later, as we have found how rapidly details as to the beds encountered or even the depth and casing of wells slip from the minds of owner and driller), we have added records of borings not primarily for water, and some references to outcrops in each section.

§ 2. Practical lessons.

The important things in water supply are quantity, quality and head. Head and quantity are not equivalent, though they often vary together. It sometimes happens, that a well will yield a water which will rise in a tube quite a distance and yet yield a dribbling supply, while another well may not have the water level at the surface of the ground at all, and yet cannot be lowered by pumping. A larger hole will generally give a greater quantity of water, but the diameter of the boring will not affect the initial head. Dynamiting will often improve the quantity of the yield, but will not usually make a permanent improvement in the head. In our review we will take up the question of quantity first.

(a). *Quantity.* An ideal well as to quantity will water your own and your neighbor's cattle, and run harvesters ad libitum. Four gallons a minute is generally ample for all farm uses.[*] The quantity of water which a well will furnish depends, first, on the beds from which it draws water never becoming dry, and second, upon their being porous. The porosity depends upon the proportion of voids, or the difference between the weight of a cubic foot dry and a cubic foot wet. Table II shows the porosity of some rocks and we see that the Napoleon sandstone, 26% of its volume being voids, is therefore an excellent water-bearing bed. Surface wells draw their water from sands and gravels. Sand is less porous than gravel, and clay is least porous of all. Shale is like clay. Limestone and gypsum are not in themselves porous, but being somewhat soluble are liable to have water channels dissolved out in them.

Surface sands and gravels if not covered by clay are apt to be dried out in a hot season, and we notice that many of the surface wells ran short during the hot weather of 1895. Surface wells striking sands or gravels under clay are much more likely to be permanent so far as drying out is concerned (and are probably of better quality), and the same thing is true of sandstone or limestone under shale or clay. The boulder clay or till has in this county usually enough clay in it to count as a fairly impervious, that is, not porous bed, the coarser sand, gravel and boulders being embedded in a clayey cement. But the distribution of the sands and gravels under or in streaks within the boulder clays which may be struck by wells is quite erratic, and no general statements can be made that will apply to any large district. Belts near the old beach lines seem to be rather better favored with alternating layers of differing porosities. Very generally there is a porous bed immediately above the rock surface.

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[*] = 1440 gallons a day = 100 gallons each for 10 people and 7½ gallons each for 60 head of stock.

As far as rock wells are concerned, however, we can make more positive statements. In the eastern part of the county, colored Coldwater shale on the map, Plate VII, wells into rock are not successful in striking abundant water, and what water there is, is likely to be salty, as is shown in the Grindstone City and other wells. In the central part of the county, colored Upper and Lower Marshall, there is no difficulty in striking a good supply of water within a few feet after striking rock. The only exception that I know of is Wright's well on Sec. 12, Hume, the record of which is very curious. It seems as though water-bearing beds must have been overlooked, but there may be peculiar local conditions. The more westerly part of this area, that of the Upper Marshall or Napoleon sandstone, is the more freely supplied with water. Farther to the west abundant water can invariably be found by going down a few feet into the Napoleon sandstone. How far that will be may be found by subtracting the altitude of the top of the Napoleon sandstone as given on Fig. 6 from the altitudes of the surface of the point where boring is proposed, as derived from Plate VIII. For example, a well on Sec. 3, T. 17 N., R. 10 E., would be expected to have to go (600 — 400) about 200 feet to strike this horizon. *To get the best results the casing should be continued from the top of the ground nearly down to the top of the sandstone as thus indicated, and be tight.* Of course the well itself must go a ways into the sandstone.

Over the area colored as underlain by the Maxville limestone, however, it will not be needful to go down so far (unless the limestone happens to be cut through by the old river valley), for although the limestone itself is not porous, it is soluble, and the calcareous sandstones, when the cement is dissolved out, are very porous, and cavities and water channels are dissolved along the joints and fissures in the purer limestone. Throughout the northern patch of limestone around Bayport wells to rock or a few feet in it get (cf. Fig. 9.) an ample supply of water often flowing above the surface, while in the southern area it is often necessary to go a little deeper, yet not over 150 feet.

(b). *Head.* In beds, not freely porous, the question of head is of no practical importance, because even if the head were such that the water would rise above ground in a closed pipe a little pumping would soon exhaust it. A well in shale or clay may yield a little water quite steadily, even in the dryest times, but will yield but a few bucketfuls at a time.

The general conditions of the head of wells and the circumstances that will produce flowing wells have been quite fully discussed in a valuable paper by T. C. Chamberlin in the Fifth Annual Report of the Director of the U. S. Geological Survey,* so that I shall confine my treatment and practical illustrations to conditions actually observed in Huron county, letting those who wish to study the subject in a broader way refer to the paper mentioned. The county furnishes, however, many suggestive illustrations of most of the important points made by Chamberlin.

By head we mean the pressure under which the water is in any bed. This determines of course how high it will rise and is commonly measured by the height above sea level of that water surface up to which it will rise. If the height to which it will rise is above the surface it will flow. If it is over 30 feet below the surface, a force pump must be used. The head is dependent upon the pressure of water in the bed. In a superficial porous bed, we find that the water sinks down into it and fills it up to a certain level which varies with the condition of the bed and the season. With the warm, dry months of summer this water level falls lower and lower, (Fig. 9) and wells which once penetrated it do so no more. When the well is dry to the bottom, the water level has fallen below it and there is a strong temptation to start boring from there and follow down after it, a course which as we shall soon see has objections. (Cf. Fig. 12). In a porous bed in which there is no outlet, the head is everywhere sufficient to raise the water level to that which exists where the water is taken in. If this porous bed extends off under impervious clays, to a region where the surface of the ground is lower than the water level at the point where it takes in its water, being covered by previous beds only or exposed to the air, wells down to it will find the water rise above the surface. But as the water level at the intake fluctuates the water level in the wells will also tend to fluctuate. An excellent example of this is seen (Fig. 9) in the wells in the Bayport limestone, to the southwest of the quarry ridge along which the limestone outcrops or is covered only with gravels. Here we find wells going down through impervious clays and tills until, upon striking the limestone, they find that the water rises higher than the surface to a water level dependent on that in the limestone. We find, however, than one well that flows in spring ceases to flow later in the summer, that another fails about the Fourth of July, and the others in still lower ground last all the year around. We are thus enabled (Fig. 9) to follow the gradual fall in the water level of the limestone as the summer goes on.

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*Pages 137-173, 1885.

Again, draining swamps lowers the water level. The water runs off instead of sinking in and remaining on the land. This is the general effect of bringing land under cultivation. Thus the drainage of the swamps which cover Lincoln, Colfax, and Sheridan, will tend to lower the water level, and the head in the underlying beds of the Marshall. The head in these beds is not solely dependent upon this factor, but yet it is one of the causes that we have to take into account in explaining the recent lowering of the head in all the wells of the Napoleon sandstone to the west.

If now the porous bed from which the supply of water is obtained has outcrops at different levels, and especially if it has points of discharge, either natural, as by springs, or artificial, through artesian wells and the like; the question what the water level will be for any new point becomes more complex. In general the water level in superficial porous beds slopes gradually toward the lakes and streams and repeats the modelling of the surface, but in less relief. Thus the depth to water is greater under hills than in adjacent valleys, but not quite as much as the difference of elevation would imply.

This remark applies, for example, to the wells in the dune sand or gravelly regions. The Napoleon sandstones, and in fact all the porous beds of the county so far as we know have outcrops or are only covered by sand near or under the lake. Near the shore therefore their water level approaches lake level and then rises as we go into the interior of the county. The head under cover will depend somewhat upon the relative nearness to the different parts of the outcrop, being most nearly dependent upon that part of the outcrop nearest. For example, the head of the Napoleon sandstone around Elkton will not be higher than somewhere between the water level on Sec. 9, Meade, where the sandstone is exposed, and the water level around Badaxe, i. e., between 660 and 740 feet above tide. Since the level of the surface near Elkton is only 650 feet or so above tide the chance of flowing wells thus indicated is good. But another class of considerations must also be taken into account. viz., the escape through wells or fissures at lower levels. This is a factor which we cannot neglect in the case of the Napoleon sandstone. Practically all the brine of the Saginaw valley is drawn from this formation, and around Sebewaing, at Oak Grove and numerous other places there are strong flowing wells. Now if these wells are, in the aggregate, but a drop in the bucket to the amount which may be rapidly taken in and percolated, then they have no appreciable effect on the head, but if not, then for a wider and wider circle about the point of outflow the head will be lowered toward that maintained at the point of outflow. For example, suppose two holes to be put down side by side where the water rises, at first ten feet above the ground in both. Then let the casing of one of them be untouched but the casing of the other of them be cut off level with the ground. The water will flow from the former and the level in the latter will be lowered. As the holes are farther apart the effect in lowering the level will be less and less marked, the greater the gap and the less porous the beds between the two wells. We have a number of illustrations of this principle in the county. Chappell's deep well at Sebewaing burst its casing and leaked into the coal mine and consequently all similar wells drawing their sources from the same stratum, the Napoleon sandstone 250-300 feet below surface, dropped two or three feet in their head or ceased to flow entirely. So for example at Elkton, when the casing of the deep railroad well was cut off below ground, so that the water was allowed to flow into a basin (whence it could find its way into the surface beds the water surface of which stood at a lower level) the wells around immediately lost their head. Fig. 12 therefore shows a common form of casing not to be recommended for this reason among others, that if the porous beds A have a good head,—more than that of the surface water,—the water will flow out from the lower beds A up and out into the surrounding surface materials C and thus lower the head of A. It is not at all necessary that such a well should be a possible flowing well. Just as soon as we strike a water stream so strong that it will fill up the old basin, in the bottom of which the new boring was put down,

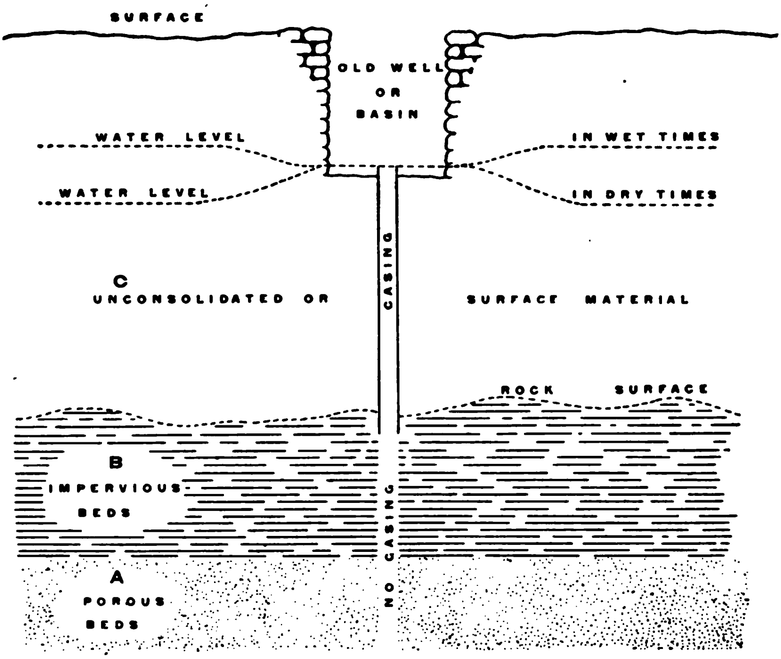

Fig. 12. Illustrates improper boring and casing, involving danger of contamination from surface waters, or of contamination of surface waters by a salty layer with strong head in A. There is also probability of reducing the head in the layer A, by flow of water into the surface layers. There is also danger of the bore hole closing, through clogging from the basin, or caving in of beds above A.

higher than the surface water would, it will tend to spread through the stoning of such basins into the surrounding surface materials, and tend to dissipate the head of the lower beds. An interesting illustration of this action is in the case of abandoned salt wells where the casing has been pulled. These are frequently flowing. The old salt wells at Port Austin and Port Crescent flow, those at Caseville are at least very near the surface and the Bayport well had a head, as I am informed, of 10 to 32 feet above ground. Now there are a number of the Port Austin wells which are salty, though shallow, whose saltness may readily be accounted for by supposing that the salty water from the flowing wells has had head enough to push its way out into the higher strata.* It might be well to case these old salt wells far enough down to prevent this action. The effect on quality of the arrangement illustrated in Fig. 12 and of insufficent casing we shall return to later. It is enough now to notice that a group of such wells large enough to be an appreciable factor in comparison with the amount of water which can freely circulate through a bed may seriously lower its head, perhaps checking its flow in some other district. I dwell on this point because this form of drilling and casing is extremely prevalent. Now although it is difficult to form even an approximate estimate as to how much water can be taken in, say by the Napoleon sandstone, it must be remembered that wherever overlaid by clay or till the flow of water which can be taken in to replace any drain upon it must be slow. Thus although the outcrop (under the surface materials of the Pleistocene) of the Napoleon sandstone is over 200 square miles, and a precipitation of 30 inches each year over that area would give (200 x 43, 560 x 2.5) 21,780,000 cu. ft., i. e. (÷ 365 x 24 x 60 = 525,600), about 40 cu. ft. per minute, when we consider how much runs off directly, is evaporated, or finds its way into the rivers by way of surface gravel beds, the outcrops where the sandstone is close to the surface being probably much less than ten square miles, if we estimate the amount subtracted, by the thirty or more flowing wells draining upon this formation and the much larger number of wells that draw their supply from it but do not flow, it becomes evident that the draft upon it must be a large fraction of the supply and hence the head will diminish almost uniformly from the highest levels to the points of escape. We must consider also that the Napoleon sandstone is subjected to drain by wells outside the county limits, and that water may escape up the line of fissures like that exposed in the Sebewaing coal mine. The exact drainage by the flowing wells we do not know, though from some observations on some of the flowing wells, and the time required to fill a pail of about 3 gallons (0.4 cu. ft.), I infer that many of them will flow more than a quarter of a cubic foot per minute.

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*It is true, however, that the Lower Marshall sandstones are sometimes salty in themselves as we can see by wells on Sec. 12, Dwight, and in Bloomfield township.

Chamberlin in the paper mentioned has suggested that a fluctuating head is a sign that the supply is being drawn on to the point of approaching the limit of supply (loc. cit. pp. 151-165). Judging by this test the supply from the Napoleon sandstone is already in that condition, for almost all the flowing wells report changes in the head from day to day depending on the weather, amounting to stoppage at times. I do not consider any definite law as proven as yet.*

Nor do I mean to say that the water supply from the Napoleon sandstone will fail entirely. Nature has her own methods of enforcing economy, and will simply lower the head, until the water running to waste by the flowing wells or escaping into the upper beds, is sufficiently cut off to restore the balance between demand and supply. But I do mean to say that a higher head could be obtained or retained by more ample and effective casing and greater economy in use.

However, in the immediate future we shall probably have an ampler supply, since the series of dry years culminating in 1895 will probably be succeeded by wetter ones.

The effect of the opening of the Saginaw coal mines should not be overlooked in this connection. As they must be pumped out, the water level for the strata in which they are located must be kept some 120 feet below the present surface or about 470 feet above tide. Now this would have no effect on the water level of other strata separated from them by impervious layers. But, as we noted, there were water channels all along the crack opened by the fault encountered by the mine, and ample indications that such channels were used. Beside this, a deep well into the Napoleon sandstone (7 of Fig. 10) was encountered in mining and the casing burst and it leaked into the mine. Furthermore there may have been other borings and wells with so little casing as to have served as channels of communication between the lower beds and those in which the mining and pumping were done. There seems to be a notion prevalent, that the abundance of water which was so large a source of expense to the Saginaw Bay Coal Company was derived in some way from Lake Huron. It is my impression that the lake had nothing appreciable to do with it and that most of it came from below. In most of the wells within a radius of four or five miles the lowering of the water at the time of the opening of the coal mines was marked. It is true, however, that this opening took place during a period of decreasing rainfall and lowering lake level, so that more than one cause was working in the same direction in the same time. But I doubt not that the draining of those mines had a marked effect in lowering the head in all the beds down to and including the Marshall sandstone.

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*Among the causes which might affect the flow thus periodically are: (1) A decrease in atmospheric pressure would allow the flow to be more free. (2) If there were points of discharge of the water under the lake, as is likely, then a rise in the lake level would raise the level in the wells, as raising the height of a dam backs the water up stream. (3) Variations of wet and dry seasons, affecting the water level at the outcrop, would slowly make themselves felt. A few of the more important observations on such fluctuations may be of interest, and will be found in connection with the wells on Secs. 8, 15, 18, and 27, Sebewaing, T. 15 N., R. 9 E.; Sec. 22, Fairhaven, T. 16 N., R. 9 E.; Sec. 9, Oliver, T. 16 N., R. 11 E.; and Sec. 13, Caseville, T. 17 N., R. 10 E. See also Sherzer's comments on the same phenomenon in Monroe county, Part I, p. 194.

The flowing wells and fluctuating head in the wells that draw their supplies from the Bayport limestone and sandstones, and occur in the northern part of Fairhaven township, have already been noticed. On the extreme southern verge of the county in the southern part of Sebewaing and Brookfield townships we seem to be entering a similar district, which will be more fully understood when Tuscola county has been studied. But before we leave this subject we have still to say a few words upon the sandstone beds of the Lower Marshall. These as we have said are less persistent, and (with possibly one exception) fade out, not being bearers of water either in the Bayport or Caseville wells. In other words they are shore deposits replaced by finer deposits to the southwest. This is a case mentioned by Chamberlin as favorable to flows* and is also illustrated by the cross-section at the foot of Plate VII. Wells in the fine grained extensions of the Lower Marshall sandstone will not affect their head, but as the outcrops of these strata lie on the eastward slope from the highest land of the county, we can expect flowing wells from them only in case they are struck on the western side of this divide at an altitude lower than the water level over their outcrops, and yet not so far to the west as to find them already too impervious to give a free supply of water. In such case, as the water level of the intermediate county stands high, we may expect as Chamberlin has shown, a head almost equivalent to that at the outcrop. The experience of Mr. B. Kreutziger in Sec. 6, Colfax, T. 16 N., R. 12 E., who went through the Napoleon sandstone into the shales below and got no increase of head, is discouraging for such a possibility in general. Three wells, however, seem to have been fortunate enough to lie in this narrow belt and to be at a sufficiently low altitude, to wit: a well at Port Crescent, the well on Sec. 19 T. 16 N., R. 13 E., near Badaxe, and Homer Filion's on Sec. 8, T. 18 N., R. 13 E. I should suppose that a few more flowing wells of this type might be obtained along the valley of Bird Creek, in the southeast corner of Colfax township, and perhaps in the lower part of Sheridan and in the Cass River valley and the valley of the upper Willow. At any rate the water should rise to near the surface at these places.

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*Loc. cit., Figs. 11 and 17.

(c). *Quality.* The quality of the water is generally good, with exceptions that we take up later. Surface wells, especially those in the sand ridges, are liable to contamination, but while wells may be noted in the list whose percentage of chlorine, unusually high for the district, indicates that they are affected by barnyard waters or by sewage, and presence of chlorine (a constituent of common salt, which is sodic chloride) is often used by water chemists as an indication of the presence of sewage contamination; in this district it would be entirely wrong on that account alone to condemn a water, for some of the very best and purest wells of the county show quite a perceptible amount of salt, which is of course not injurious, and up to a certain point only renders the water more palatable. Indeed it is remarkable what an amount of salt the palate can become accustomed to, and not notice. A water free from salt will taste flat and insipid, after using a slightly saline water for awhile. It is hard to say what the limit of drinkable water is. We have found a water with over 4% of salt used, although under protest, and one-half of one per cent of salt is soon quite unnoticed. Cattle and to a less degree horses all enjoy a moderately salty water. A connection between diabetes and mineral water has been suspected, but not at all proven. There is an interesting field of research open here for the physician.

In the area of the Marshall sandstones the percentage of mineral constituents is generally low. This is so markedly the case for the Upper Marshall,—the Napoleon,—that we find it comparatively fresh, even when there is salt water above it. One suggested explanation of this as follows.*

The total amount of salt which Michigan has produced to 1896 is very nearly 75,000,000 barrels. Almost all the salt of Saginaw

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*It is also quite possible that the water was very early freshened as it is an emergence sandstone.

Bay, Midland and Gratiot counties was derived from this formation, though not quite all. These counties produced practically nine-tenths of the salt until 1879, since when they have had a less and less share. Though we have not the statistics to separate the production accurately, it seems safe to say that two-thirds of the whole production or 50,000,000 barrels of salt were derived from the Napoleon sandstone. At 280 pounds to the barrel, and allowing an 86° brine which would yield certainly not more than 22.10% solids, or allowing for the other mineral constituents and loss of salt in manufacture, supposing six times as much brine by weight to be used as salt was produced, and this, as the analyses given in Vol. III of these reports show, is too low an estimate of the volume of brine required,we would have 84,000,000,000 pounds of concentrated brine abstracted from the formation. If a cubic foot of the sandstone (See Table II, p. 90) holds 10% voids, it would contain about 100 ounces of pure water or about 116 ounces, or 7.25 pounds of brine. Thus nearly 11,600,000,000 cubic feet of sandstone would have to be drained to furnish this brine, or 42 square miles of a sandstone 10 feet thick. But in addition to the brine made into salt, there has been a great deal wasted and a great deal abstracted by the salty flowing wells, like the Oak Grove well, that reach the formation. Moreover all through the geological ages preceding the ice period while the Marshall existed as a basin with the water level over its outcrop higher than that over the center, there must have been a tendency for the water to work up by every crack and crevice (e. g. such a fault as we find in the Sebewaing coal mine) toward the center of the basin, to be replaced by fresh water working in at the margin. Thus the tendency will have been for the water to become fresher in the more porous layers near the margin of the basin.

This is an important fact, for we have only to compare Mr. Leipprandt's wells on Sec. 13, Caseville, or the Brewery well at Sebewaing with Mosner's near by, to see that in case there is too much mineral matter in the water it is probable that casing down to the top of the Napoleon will help matters (casing off tightly with rubber washers or a seed bag to prevent the heavy brine from working down). Wells traversing the overlying Michigan series have more mineral matter than is necessary or frequently than is healthy or palatable, i. e., many wells to the east of the line which

I have marked as the outcrop of the gypsum beds, or in the lower part of the map the line of the top of the Napoleon sandstone. Of course some beds east of that line are too shallow to be affected by the formation, drawing their supply from the drift, or Bayport limestone and sandstone;·others have so strong a current from the Napoleon sandstone as to weaken the water until it is comparatively drinkable, but speaking generally in the district thus marked off and colored on the map, wells in rock are likely to prove unsatisfactory, being highly charged with sulphates, and very likely salt also. Gypsiferous waters, technically called selenitic, our tests have not sharply distinguished from the allied group of more cathartic sulphated waters which also contain sodium and magnesium sulphate, but it is my general impression, from the taste and reported effects that the northern area in Chandler contains more calcium sulphate in proportion than the southern area in Fairhaven and Winsor townships.

Mr. McCoubrie's well on Sec. 7, Chandler, is cased deeply and yet is salt, but as the casing is smaller than the hole, and as the water becomes fresher after pumping, I believe the casing leaks and lets the heavy brine work slowly down to the bottom of the well.

The Burton ale of England is said to owe its peculiar excellence to the gypseous waters from which it is made. Generally speaking brewers find artesian waters satisfactory, but seek as low a percentage of mineral as possible.

Almost all the waters of our list which are graded as more than low in mineral matter are bad boiler waters, in other words, all except the best sandstone waters. The sulphates of lime are especially bad. The best remedies are frequent blowing off, and, for calcium and sulphate the use of salsoda, and using very hot feed water. As regards iron and the carbonates of lime, etc., some help will be obtained by letting the water stand in a tank exposed to the air some time before using, just as in salt manufacture, for the iron and lime will then spontaneously separate out to a large extent. The following well at Grassmere is said to furnish an excellent boiler water. So should the waters of the Napoleon generally, when properly cased. Occasionally there is a well that foams somewhat badly for boiler use.

The next section is written by Prof. Davis and gives his account of the waters of the middle district, which are in general much less charged with mineral matter than those of the other districts.

§ 3. Wells and well waters of the middle townships of Huron county. (By C. A. Davis.)

The territory assigned to the writer for examination was a strip a township and a half wide on either side of the line between ranges XII and XIII east, i. e., the middle north and south road of the county. This area was subsequently changed somewhat by Dr. Lane who added to his own territory the east half of Chandler township and of the township south of it, because of the ease with which they could be reached from his headquarters and by the railroad. After the completion of the survey of this territory parts of Grant and Brookfield townships were assigned to me with headquarters at Owendale.

The wells of these sections may be classed under the following heads:

- (a) Dug wells.
  - (1) Springs,
  - (2) Boarded or planked,
  - (3) Tiled,
  - (4) Stoned.
- (b) Drilled wells.
  - (1) In the drift,
  - (2) Through the drift to rock,
  - (3) In rock.

Springs were comparatively rare, and were found most commonly along stream banks, where the gravel deposited by the stream at some earlier time had been cut through to an underlying clay. Such springs where they were near the house were usually the source of supply for domestic purposes and a reservoir was made by sinking a headless barrel around the spring. The water of such of these springs as were examined was found to contain rather more calcium salts, chiefly carbonates, than deeper wells.

The most common form of curbing for wells in newly settled districts where the wells were comparatively shallow and dug through clay or gravel soil was a box of boards or planks. Such wells were often noticeably foul from the decay of the timber used and from material which had mechanically mixed with the water.

A few wells were noticed in which a large sized drainpipe or ordinary tile or cement was used as curbing. Such wells are free from the objections to which planked ones are liable, and are more permanent. By far the larger number of dug wells visited were stoned up, either with sandstone, drawn from a distance in some cases, or with erratic boulders from the drift. In either case the use of this form of curbing is open to very serious objection, since the spaces between the stones permit the entrance of surface water during storms, and also of that which runs from the surface through cracks and channels, which in clay soil are far from uncommon. During the long continued series of dry seasons which have prevailed for the past years many of the dug wells, partially or entirely failing, have been deepened by boring small holes by hand with augers of various sizes to underlying water-bearing strata. These holes were commonly left without tubing and the water supply was frequently not permanently improved unless the water-bearing stratum which was found, gave a strong up-current, which could keep the opening made by the auger clear. Only one case was noted in which a dug well was flowing over the top.

The water from such of this type of wells as were chemically tested varies characteristically with the soil, or rather with the form of drift deposits in which they were dug, or from which the water came. The water from "veins" in the clay or clay gravel, generally contained more dissolved mineral matter than that from sand or gravel. The mineral matter was frequently largely calcium carbonate, although the sulphate was not wanting. The presence of iron was frequently shown by the reddish color of the "tea-kettle scale" and in nearly every case the presence of chlorin was strongly indicated by the usual test. The water from sandy layers, as would be expected, was more free from the calcium salts, and in general contained less mineral matter.

The character of the soil also has much to do in determining the kind of wells which are most common in a given district, and in studying the wells of the region traversed this was well shown. In sections where the surface layers were porous and underlain at a depth of several feet by impervious strata, or where the drift materials were clay and sand and gravel intermingled in layers, dug wells as described above were almost exclusively used. Where the surface material was a compact clay without intermixed sand, or where the rock was near the surface, the wells were frequently drilled. If the clay deposit was very deep the drill would sometimes strike a water-bearing stratum before rock was reached, and along the southern border of Grant township the wells were frequently of this character. The water from such wells was practically the same as that from those dug in the clay. In many places, however, the drill would reach rocks before water would be found in any quantity, especially if the overlying clay was compact to the rocks.

An interesting region was found just west of Ubly, where there are many high clay ridges. On these the water was nearly all obtained from deep drilled wells which went a foot or two into the underlying sandstone ninety or a hundred feet below the surface, while the wells in the lower flat land on either side of the ridges were not twenty or thirty feet deep to the same sandstone, showing that the rock surface was in the main nearly uniformly flat underlying the regions. Where the surface material is rather thin and porous and the rock directly below, wells drilled a considerable distance into the rock are the only reliable source of supply. In such cases drilling is continued until a "vein" of water is struck, and, judging from reports, the rock is more or less intersected with small channels in which the water collects, as it is said that the drill drops, at the time water is found, as if a hole had been reached.

The water from this class of wells was so characteristically pure and free from mineral matter (see Anal. Badaxe water p. 137) that it was possible to tell by the taste alone whether water came from the sandstone or from the clay above it. Calcium was usually present in traces in the form of the sulphate, and chlorin was either absent or present in small amounts. With the exception of two drilled wells on the middle line of Sec. 18, Huron township, and two dug wells on the N. E. ¼ of Sec. 12, Dwight township, and one in Paris township, near the quarter line on the north side of Sec. 20, the wells visited by me alone were remarkably uniform in the character of the mineral constituents. The two wells mentioned as exceptional were quite brackish, and contained in addition considerable calcium sulphate. In some neighborhoods the iron dissolved in the water was noticeable to the taste, and one well about 100 feet deep was found at Pinnebog P. O., and was quite strongly impregnated with hydrogen sulphid. One well a half mile west of Owendale P. O. was found which was strongly gypsiferous. In the day's trip to Sand Beach to assist Dr. Gordon, I found the wells about there, in Bloomfield and Sigel townships very brackish or even unpleasantly salt, and to the west of the territory assigned to me the wells contained both salt and gypsum in large quantities.

To sum up the results of the examination, the well waters of the section are remarkably free from mineral matter, except along the northern tier of townships. The water from the sandstone is very pure and more so than from the drift above it. All the waters of the section contain chlorin and in some districts the amount is largely in excess of that normal to well waters of the country as a whole, and in other formations might be looked upon as an indication of bad drainage and contamination, but in this region, the fact that salt-bearing formations are so near, both horizontally and vertically, and that there are many old salt wells in the vicinity, affords a satisfactory explanation of the occurrence of chlorids in such quantities.

No flowing wells were found in the region, except one just east of Badaxe, until the valley of the Pinnebog was reached. South of Elkton, about Owendale, and south and west of that point, a considerable number of such wells were found, and also some that formerly had given good flows, but within a year or two had ceased flowing.

§ 4. Mineral waters.

So much for the waters as drinking water, but, like some other things, what will make a well man sick may often make a sick man well, so that some of the less potable waters may still be useful.

The water from the well of Mr. Raither on Sec. 13, south of Bayport, has been brought to the Bayport resort to be used as a cathartic and southeast of it are a number of wells still more powerful. Most of them that are used regularly are mild and one can quickly become used to them, but in hot weather when one is tempted to drink more, and especially if neighbors come to help in the thirsty work of harvesting, they give their characteristic effects. Some are really too strong to drink at all. Such cathartic wells are low in chlorides but strong in sulphates. The sulphates of magnesia and soda are probably the most efficient agents, but no complete analysis of the waters of these wells has as yet been made. Free sulphuric acid is sometimes to be detected.

Then there are the flows from abandoned salt wells. Port Crescent has quite a local reputation, and it seems to me that for tonic salt baths, such wells, which flow, as we have remarked, at Bayport, Port Crescent, and Port Austin, should be an attractive addition to the resources of a summer resort. The deep well at Harbor Beach, however, has been the most exploited in the county, and its analyses are given in Table III.

The way in which some of the wells rust tinware points to the presence of free acids, probably free sulphuric and carbonic acids, and many of them are slightly chalybeate or iron-bearing, judging from the red coating they throw down. However, the iron may be derived from the casing.

One or two cases have been reported where malarial cases have been greatly benefited by drinking the water from these deep wells. Whether there is any chemical ingredient in the water (one of the wells was Mosner's well in Sebewaing) that was helpful, or whether the change was really due to the leaving off drinking swamp water, the real trouble being bad water and not bad air, I shall not presume to decide.

The amount of iron necessary to make a chalybeate (or ferriferous) water of marked medicinal effect is very small; many of the wells seem to contain some iron, especially those otherwise strong in mineral matter.

TABLE III.—ANALYSIS OF HURON COUNTY WATERS.

Chemical components.	Helderberg brines.			Berea brines.		
	(1)	(2)	(3)	(4)	(5)	(6)
H_2O				776.761	767.197	789.764
$CaSO_4$	0.58	0.9936	0.90	0.129	2.539	2.623
$CaCl_2$	41.07	62.6636	56.89	31.274	3.000	5.373
			Fe. tr.			Fe_2O_3 .032
$MgCl_2$	22.44	5.3542	4.85	15.675	1.591	4.106
$MgBr_2$	0.84	24.8400	22.50			
KCl	3.07	37.7788	34.22			
NaCl	263.29	179.2391	162.64	176.161	225.673	189.134
H_2s		0.2271				
Loss	14.41	0.0004				
Total solids	285.7	311.6000	282.00	223.239	232 803	201.236
Sp. Gr.	1.187	1.180		88°	84°	

Note.—These analyses are all reduced to parts per thousand, i. e., grams per kilogram or ounces per cubic foot, nearly, from various forms of statements as referred to. It has been assumed that the respective chemists in stating the amount in grains per imperial gallon, etc., have really taken 10 lbs. of the water a gallon, regardless of the specific weight of the brine. It is quite common to neglect the specific weight of mineral waters.

(1) Hetherington & Rasher, analysts; for U. S. Alkali Co., Sp. Wt. 1.187, from grains per imperial gallon divided by 70.

(2) S. P. Duffield, analyst, left unchanged from grammes per litre, but Sp. gr. = 1,180 at 60° F. Harbor Beach.

(3) R. C. Kedzie, analyst, from grains per imperial gallon, dividing by 70, with tr. of Fe., both these analyses from Vol. V, p. 82. These two are earlier than No. 1, but all three are of waters from the same well.

(4) From Vol. III, p. 183, and Vol. V, Part II, p. 75, from percentages, 88° salinometer; Ayers' well, Port Austin.

(5) S. P. Duffield, from percentages, 84° salinometer, Harbor Beach 702 ft. deep. Another report gives 98.7% of the solids NaCl.

(6) From percentages, 78.5° salinometer, Thomson Bros.; White Rock 566 feet deep, Vol. III, p. 184, and Report on Centennial Exhibit.

(7) A. B. Prescott from well about 2000 feet deep, but plugged off at 550 feet, see below; main flow from Napoleon. Sp. Wt. 1.0029. Old Bayport, T. 17 N., R. 10 E.

(8) A. B. Prescott, Oct. 13th, 1891, from well 328 feet deep at Bayport, main flow from Napoleon sandstone, but Michigan series not cased off, well flowing all the time; from grains per gallon by dividing by 700÷12.

(9) Bayport Station, 19 foot well, A. B. Prescott. Residue of half a litre tested for K, Li, and Br. Sp. Wt. = 1.0007. Faintly alkaline, saline solids, 0.5006 per thousand.

(10) Dr. R. C. Kedzie, well 15 feet deep pumped, Bayport, by dividing by 70 from grains per imperial gallon. Hardness 12° temporary, 6.5° permanent.

(11) Is a sanitary analysis of a shallow well at (Sand) Harbor Beach. See Water Supply Paper of the U. S. Geol. Survey, No. 31,

	7	8	9	10
Ca $H_2(CO_3)_2$	.451	.038	.344	.148 Ca CO_3
Ca SO_4	.360	.440	.019	.000 Ca SO_4
Fe CO_3	....	.044	.009	....
Mg $H_2(CO_3)_2$	....	.100	....	.081 Mg CO_3
Mg Cl_2	.198	....	.016	....
Silicic acid	.015	.144	.010	....
Na Cl	2.379	.925	.022	.007 Na Cl
Na H CO_3	....	.201	.078	.014 Organic
Total	*3.403	1.892	.499	.200

* By summation.

p. 47. The above analyses I have all incorporated in that paper, where their statements in other forms will be found.

No. 11 is by Prof. V. C. Vaughan at Ann Arbor.

Nos. 12 and 13 are partial sanitary analyses of the Badaxe water supply by F. S. Kedzie and are from wells 200 feet deep in the Upper and Lower Marshall sandstones. See § 6, under T. 16 N., R. 13 E. No. 12 is from the dead end of the pipe (the references in water supply paper No. 31 are erroneously interchanged, and the increase in organic matter over No. 13 is doubtless due to growth of algæ, while the increase of inorganic matter may probably be iron dissolved by free CO_2 in the water from the pipe.

No.	11.	12.	13.
Number of bacteria in 72 hours	.812	....	....
Albuminoid ammonia	.00008	.000072	.000048
Free ammonia	.00002	.0000024	light tr.
Permanganate reduced	.003	....	....
Chlorine as NaCl	.002	....	....
Organic residue	.020	.100	.090
Inorganic residue	.035	.235	.204
Total residue	.055	.355	.295
Hardness	5°.5	5°.9	5°.2

Of these analyses the most interesting geologically and practically are those of the brine near the bottom of the Harbor Beach well. That the water analysed by Dr. Kedzie is as strong in K and Br as shown there can be no doubt. Some of it is still preserved at the Agricultural College and used for exhibiting tests upon bromine. That the sample was artificially doctored there is no reason to believe, in view of the fact that the well was used and continued to be used only for salt manufacture, and so far as I know there was no attempt made to sell the property.

All parties seemed to be much surprised at the result of the analysis, which was repeated, as shown. The most plausible supposition is that the sample contained an extra large amount of the bitter water struck at 1860 feet, which was later diluted by lower brine of more normal composition at 1875 feet. It will be noticed that these brines are somewhere in the Helderberg dolomites, probably (possibly Hamilton i. e. Traverse) and not in the Berea which as elsewhere in the county was a strong pure brine, the analysis of which is No. 5. Nos. 4, 5 and 6 are from the Berea grit and show clearly the progressive increase in solids with depth. Nos. 12 and

13 show the pure water of the Marshall sandstone. No. 8 shows the same water mixed with the sulphated waters of the gypsiferous Michigan series above. No. 7 penetrates deeper into the lower Marshall and we see that the $CaSO_4$ is relatively reduced while the salt and carbonates increase,—just what might be expected. Nos. 9 and 10 are shallow wells showing the water yielded by the Bayport limestones and sandstones,—a little hard and not as low in mineral matter as the Badaxe, but less mineralized than most of the water in the state. Probably the circulation of water in these beds is quite free, as I have indicated in discussing Fig. 9, and an analysis in sand would not be very different. Such analysis I take No. 11 from a Harbor Beach well to be, for I know that the deeper wells like that at the Dow House are salty.

§ 5. Chemical tests of well waters.

In a county as flat and with as few outcrops as Huron county, any thought of following the stratigraphy was out of the question, unless the wells helped us to do it. Information gathered concerning the beds passed through is valuable so far as it goes, but often the important facts have passed from the memory, and again memories are deceptive. I had the depth of the Port Crescent salt wells reported to me from memory as all the way betwen 900 and 1,500 feet deep. It was therefore very desirable to have as a check something that could be tested as a present fact, and it seemed to me possible from things I had heard about different wells, that something might be made by testing them. Practical tests in a small way were hopeful, and as the proof of the pudding is the eating, I resolved on a systematic testing of the wells. It was obviously necessary that the tests should be of the simplest and most rapid description, and they could be but qualitative.* "A pocket case containing a set of reagents for making the ordinary qualitative tests for the more common metals forming soluble salts was devised and taken into the field, equipped with test tubes, etc., but was abandoned after a few weeks' trial as too cumbersome, and from this time on a discarded bicycle-tool-bag, respectively compass case," containing a few physicians' casevials of reagents and a test tube constituted the laboratory. The brief experience had shown that the waters were practically free from substances easily recognizable, except the sulphates, chlorids, calcium and iron, and search for others was not practicable in the field. Under these circumstances the reagents selected were,—silver nitrate, barium chlorid, ammonium oxalate and tannic acid, the latter not perhaps the best for the purpose, but the only available one at the time it was adopted. A small quantity of the water to be tested was used to rinse out the test tube thoroughly, then not more than one-half inch of the water was taken into the tube and a drop or two of the reagent required was allowed to run into it. If chlorin was the substance sought and after the addition of silver nitrate a mere opalescence appeared, the result was noted as indicating a 'trace' of chlorin. If the silver nitrate gave a milky appearance to the water, up to the point of curdiness it was noted as 'Cl low' or 'low plus;' if a curdy precipitate formed, it was said to be 'medium' or 'medium plus,' according to the promptness with which the curdiness appeared, and if the water had a brackish taste, it was noted as 'Cl strong,' and the curdy precipitate was very marked in such waters.

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*All in quotation marks is from Prof. C. A. Davis.

"After the test was made it was usually repeated, and the tube was very carefully cleaned, before another substance was looked for. In this way the wells were tested quantitatively in a rough way, as well as qualitatively.

"The other mineral constituents could not be graded so accurately as the chlorin, but the density of the precipitate and the rapidity with which it formed gave a fairly good indication of the relative amount of each substance present, and by the aid of these tests we were enabled to determine the mineral impurities of the wells visited, with sufficient accuracy for the purpose."*

I may remark that the chemicals above mentioned have the advantage that they can be carried around in a dry form, and dissolved in rainwater as needed. Citric acid may be used instead of HCl for the same reason.

A few suggestions as to recognition of the substances by the general behavior of the waters, may be also interesting. Lime and to a less extent magnesia and iron make tea kettle scale; a scale of carbonates, will dissolve in hot vinegar quite rapidly with effervescence, but the sulphate of lime dissolves more slowly with no effervescence, and has a fibrous appearance when carefully examined, and is softer. An iron water makes a red scale and turns tea black or a weak yellow solution brown, practically the same reaction as that which we used with tannic acid. Cathartic effects are generally due to sulphate of magnesia or sulphate of soda.

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*All in quotation marks is from Prof. C. A. Davis.

As Prof. Davis remarks above, the testing was qualitative, but we give below a table which he prepared showing roughly the quantitative equivalents of his chlorine tests. As the difference between medium and strong is one of taste it is more uncertain, and I found that as I was in a region, and staying at hotels at Sebewaing and Bayport where there was more salt naturally in the water, than was usual in the district in which Davis worked, my division line between medium and strong was higher than his. In order to grade more accurately these wells with much mineral matter I had recourse to a physician's urinometer, which measures the specific gravities. This consists of an instrument like a salinometer,—a cylindrical vase in which floats a glass bulb with mercury in the lower end, and the upper end prolonged into a stem like a thermometer, which is usually divided into 60 divisions, with the 0 at the top, at the point at which it floats in pure water. The heavier the water is, i. e. the more salt it contains, the higher the bulb floats and the excess of weight of equal volumes measured with reference to the volume of pure water is measured on the urinometer scale and the reading gives about twice the salinometer reading and about eight times the percentage of salt. For example, if the urinometer reads 16 the salinometer will read 9 minus, the percentage of salt will be somewhat over 2%, the specific gravity will be 1.016 or a cubic foot of the water (thirty quarts) will weigh nearly 16 ounces more than a cubic foot of pure water would under similar conditions.*

My tests around Sebewaing indicated that by taste I usually classed a well with a specific gravity of 1.002 as moderate, but anything above that as strong or "medium plus." Hence the range of "medium" in my case would be up to 2.6 parts per thousand of solids, and if as in analysis (8) the salt (NaCl) was about half the solids (and the wells were generally strong of sulphates as well as chlorides), my "medium" would correspond to Davis's "medium plus." The range of meaning in the other components is still less exact, but speaking generally, "SO_4 strong" would correspond to a saturated solution of gypsum, about 178 grains per imperial gallon or 2,170 to 2,540 parts per million.*

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*Approximately; the table on pp. 177-179 in Vol. III, of our reports gives more accurate figures, but that is itself not quite accurate, and the varying percentages of different salts prevent great accuracy, so that the rule above is probably practically as accurate as the table. The temperature ought also to be considered. Urinometers are usually graduated for a temperature of 60° F.

The following are Prof. Davis's notes to determine the value of his Cl tests during the summer:

100	milligrams	NaCl	to	litre	H_2O	=	no saline taste	Cl low—"
200	"	"	"	"	"	=	" " "	Cl low—
300	"	"	"	"	"	=	" " "	Cl low—
400	"	"	"	"	"	=	very slight saline taste	Cl low—
500	"	"	"	"	"	=	slight saline taste	Cl low+
600	"	"	"	"	"	=	faintly brackish	Cl low+
700	"	"	"	"	"	=	faintly brackish	Cl low+
800	"	"	"	"	"	=	brackish	Cl medium
900	"	"	"	"	"	=	well marked brackish	Cl medium
1000	"	"	"	"	"	=	well marked brackish	Cl medium
1100	"	"	"	"	"	=	well marked brackish	Cl medium+
1200	"	"	"	"	"	=	well marked brackish	Cl medium+
1300	"	"	"	"	"	=	well marked brackish	Cl medium+
1400	"	"	"	"	"	=	slightly salt	Cl strong
1500	"	"	"	"	"	=	slightly salt	Cl strong
2000	"	"	"	"	"	=	well marked salt	Cl strong+

"So our 'Cl low' or 'traces' probably indicate salt present as high as 2 parts to 10,000 of water, 'low' up to 5 parts to 10,000, 'low +' up to 8 parts to 10,000, 'medium' up to 1.1 parts to 1000, 'medium +' up to 1.3 parts to 1000 and strong above 1.3 parts to 1000; in every case, provided the chlorides of calcium and magnesium were not present (which seems likely from the faintly saline tests which are present in nearly all my solutions). The lowest amount of salt I could get to give a reaction was two milligrams to the litre, — 2 parts to 1,000,000, — from which I got a very slight opalescence, forming very slowly. In these experiments I used the same silver nitrate which I used all summer, and the results may have additional interest on that account.†"

The main result of these tests is to show that the Napoleon sandstone has less mineral matter, and especially less of sulphates in proportion to chlorine than the overlying beds, and a parallel phenomenon has long ago been observed by Garrigues, in the brines of the Saginaw River (Vol. III, pp. 182-183). Below the Napoleon the salt reappears, but the sulphates are not so prominent, and the analyses of the deeper wells show a predominance of magnesium and calcium chlorides.‡

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*Its solubility varies somewhat with temperature, being greatest at 95° F., and also with the other substances in solution.

†Extract from letter of C. A. Davis, Feb. 12th, 1897.

‡The varying percentage of sulphates on the one hand and of the chlorides of magnesia and lime on the other in association with these brines suggests some interesting questions. How can the gypsum which exists in the sea water be so completely got rid of as in analysis (4) or must we suppose that the sea was then deficient in a sulphate of lime? The latter supposition in view of the beds of gypsum that occur both above and below seems hardly likely, and one is tempted to conceive the sulphate of lime as having been chemically replaced. But the only place where the sulphur can be disposed of is in the sulphides. We find, in fact, brine-bearing sandstones, the top of the Napoleon sandstone, or the sandy layers exposed at the Point aux Barques lighthouse, heavily charged or entirely encrusted with sulphides. But this disposition of the sulphur implies a reducing or

§ 6. Systematic catalogue of wells and borings.

Explanations and Abbreviations.

In so many records taken by different men at different times perfect uniformity in description is not observed. But in general the first thing given is the location of the wells within the section, according to the system which has been for some time adopted by the Survey, i. e., by the number of paces north and west of the southeast corner of the section, assuming ordinarily 2000 paces to the mile, and that wells are ordinarily about 50 steps from the road. Thus locations beginning 1950 N. are on the north side of the section. Occasionally wells are located from some other corner, or by feet, instead of paces, or described by the fraction of the section in which they occur, but it is explicitly stated in such cases. Next generally follows the depth, and the depth of bed rock, or the depth of casing, in feet and then the results of tests for salt (Cl) sulphuric acid $H_2 SO_4$, sulphates (SO_4), and lime (Ca) and iron (Fe), as above described (§ 5), stating whether they are present in large quantity (strong or str.) in moderate quantity (med. or mod.), in slight quantity (low), or in traces (tr), or absent (0). Next comes the elevation above sea or tide level (A. T.) which sometimes precedes, sometimes follows the altitude in feet. The elevation above Lake Huron is about 581 feet less. When the water tasted markedly of mineral, the specific gravity test with the urinometer was often made (Sp. Gr. or Sp. Wt.).

When the well flowed the temperature was commonly noted with a pocket thermometer. That read by Davis seemed to read about 2° higher than that by Lane. The latter has been compared with Green's thermometer No. 7536 and agrees within a degree. The general division of field work has been given above. In certain cass of doubt the field observer is indicated by initial; (D) Davis, (G) Gordon, (L) Lane.

The records are arranged first by townships then by ranges, beginning at the S. E. and then by sections.

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deoxidizing action, and it may be noted that the sulphides tend to form near and replacing fossils or in blue or black shales which owe their color to the organic matter contained, which may serve as a deoxidizing agent. The general reaction would then be that organic carbon in oxidizing would bring into solution the iron as bicarbonate, which would partially then interchange with the lime, forming sulphate of iron (Geol. Sur. Miss. III, 1892, p. 19), which would then in presence of more reducing carbon compounds, be reduced to the sulphide of iron. According to this scheme the sulphides would form near the reducing agents and the sulphates and bicarbonates farther therefrom. In the same way the carbonic acid slowly generated by decomposing organic matter, would crowd out the sulphuric acid from the sulphate of lime to a slight extent, which would in its turn claim a certain proportion of the sodium (Na) from the sodium chloride (NaCl), thus giving rise to the complicated associations that we find.

Sebewaing Township (T. 15 N., R. 9 E.).

Section 1.

1950 N., 1280 W., 80 feet deep, 65 to rock, with Cl low. SO_4 trace. J. Graves, owner. A. T. 631.

1950 N., 880 W., 122 feet deep, 68 to rock; Cl low, drilled by A. Jahnke for Ch. Marotski. Chas. Falle drilled 300 ft., near by in a vain attempt to obtain a flow.

620 N., 50 W., 160 feet deep; Cl low, SO_4 low. A. T. 629.

1000 N., 980 W., 11 feet deep. A. T. 630.

Section 2.

In southwest quarter. Drilled by J. Russell for Henry Gettel, A. T. 630.

DRILLER'S RECORD.

	Thickness.	Total.
Clay	62	62
Hardpan	6	68
Limerock	2	70
Slate	20	90
Sandrock	30	120
Limerock	8	128
Sand rock (Napoleon sandstone)	65	193

and in the same quarter, J. Russell drilled a well for Mrs. J. Gettel as follows:

	Thickness.	Total.
Old well	66	
Hardpan	4	70
Limerock	5	75
Slate	27	102
Dark sandrock	15	117
Sandrock	10	127
Limerock	4	31
Sandrock	2	133
Limerock	6	139
White (Napoleon) sandrock	15	154

980 N., 920 W., first well 100 ft. deep, SO_4 low, second surface well dry. A. T. 630.

1360 N., 820 W., 12 feet deep, dug. A. T. 628.

980 N., 1440 W., 190 feet deep, 80 to rock, the first 50 or 60 feet "slate" (shale), then 40 feet and more sandstone; Cl low. L. Ebert, owner. A. T. 622.

1640 N., 1950 W., 140 feet deep, 60 to rock, the casing driven 90 feet, i. e., 30 feet into soft rock; Cl med. SO_4 tr. A. T. 616.

Section 3.

780 N., 1950 W., deepened from 75 feet, which may be about the depth to bed rock, down to 135 feet, at present Cl med. SO_4 tr. *It was harder when shallower.* A. T. 616.

1240 N., 1950 W., 157 feet deep, about 70 to rock. Drilled by C. Hofmeister for C. Winter. The water never overflowed, though at first it came just to the top, and always remains nearly full. Cl low. SO_4 tr. There is another shallow 6 foot well.

1700 N., 50 W., Depth to rock 60 feet, total depth 160 feet. Cl med. SO_4 low. Carl Beck, owner. A. T. 628.

620 N., 50 W., depth 290 feet. A. T. 620.

50 N., 1100 W., Cl med. SO_4 low. See Russell's record following, probably of this well. A. T. 620.

Section 4.

1130 N., 1450 W., well 18 feet deep, water yellow and probably surface water. A. T. 610.

800 N., 50 W., well 210 feet deep, and around here it is 80 to 90 feet to rock; Cl. med. SO_4 trace. Geo. Gremel, owner. A. T. 610.

1120 N., 50 W., 205 feet deep, 96 to rock, and then sand rock all the way down. Water begins at about 160 feet and at 205 feet we pass through the waterbearing rock. F. J. Gremel, owner. A. T. 612.

1890 N., 50 W., 20 feet deep, not drilled. A. T. 608.

Section 5.

50 N., 50 W., shallow well in surface sand, of which there are extensive ridges and dunes on the south line of the section. A. T. 612.

Section 7.

Southeast quarter. Test well by J. C. Russell for J. C. Liken on Kobeld's land. No. 1, May 9th, 1894. A. T. 590.

	Thickness.	Total.
Clay	52	
Hardpan	4	56
Loose sandrock	2	58
Sandrock	2	60
Light slate rock	6	66
Fire clay	2′ 7″	68′ 7″
Black slate	4′ 8″	73′ 3″
Fire clay	5′	78′ 3″
Slate and iron	1′ 4″	79′ 7″
Coal	1′ 2″	80′ 9″
Dark sandrock	1′ 8″	82′ 5″

Test well No. 8. on Kobeld's land near the railroad, as recorded below. A. T. 590½. Record as follows:

	Thickness.	Total.
Clay	43	
Sandstone	15	58
Shale and slate	6	64
Coal	6 in	64½
Hardpan	8	72½
Slate	17	89½
Coal	4	93½
Fire clay	3	96′ 6″

No. 9. Test well on Kobeld's land (Coreyell's series). Depth 99 feet. A. T. 590. Record as follows:

	Thickness.	Depth.
Clay	50	
Sandrock 2 ft. very hard	15	65
In black slate	4′ 6″	69′ 6″
Coal	6″	70
Hardpan	3′	73
Blue shale	5′	78
Coal	15′ 4″	93′ 4″
1 ft. in fire clay		99

S. E. ¼. No. 2 test well for J. C. Liken on Kobeld's land. Probably put down May 26th, 1894. Depth 85 feet 9 inches.

	Thickness.	Depth.
Clay	52	
Loose sandrock	1	53
Sandrock	7	60
Iron pyrites	1	61
Black slate rock	5	66
Fire clay rock	1	67
Slate rock	14′ 4″	81′ 4″
Coal	2	83′ 4″
Brown rock	2′ 5″	85′ 9″

S. E. ¼. No. 2 test well for Sebewaing Mining Company. Depth 91 feet 11 inches. About 590 A. T. Record as follows:

	Thickness.	Depth.
Clay	50′ 6″	
Hard-pan	5′ 6″	56
Loose sand rock	1	57
Hard pan	4′ 10″	61′ 10″
Soap or slate rock	13′ 3″	75′ 1″
Black slate rock	4′ 4″	79′ 5″
Coal	1′ 6″	80′ 11″
Fire clay	6′ 6″	87′ 5″
Fine sand	4′ 6″	91′ 11″

No. 1 test well for Sebewaing Mining Company. Depth 130 feet. About 590 A. T. Record as follows:

	Thickness.	Depth.
Clay	50	
Hardpan	7	57
Loose sandrock	2	59
Small vein of sand		
Hardpan	3	62
Black slate	13	75
Light slate	19	94
Black slate	24	118
Fine sandrock	12	130

Section 8.

S. W. ¼. Block 2, Lot 9, of Chappell's subdivision, 980 N., 1600 W. Cl med. +, SO_4 tr. Henry Muller. Original depth 273 ft. It was deepened in August, 1896. This well was cased to 192 feet, afterward to 194 feet, and the deep casing has improved the water. Flow was strong; 2 gallons in eight seconds. T. 52.5°; 10 foot head. Record as follows:

	Thickness.	Total.	Correlation.
Old well	57	......	Pleistocene.
Loose sandrock	2	59	Coal Measures.
Light slate rock	24	83	
Black slate rock	5'7"	88'7"	
Coal	3	91'7"	
Dark sandrock	3	94'7"	
Water sandrock	10'5"	105	
Offset at	126½	......	
Slate with hard streaks	102	207	Grand Rapids group.
Dark lime rock	16	223	
Slate with hard streak	12	235	
Soft slate rock	12	247	
Sandrock	67	314	

1360 N., 1316 W. About 50 feet southwest of corner of Young and Center streets, Lot 3, Block 2, of J. C. Liken & Co.'s plat. J. Bauer, owner. A. T. 596. Driller's record as follows: A. C. Lane was present at the drilling and the notes in brackets are his.

Clay (old well 20')	48	......	
Hardpan (clay with little stones, Sept. 2)	16	64	Pleistocene.
Light shale	10	74	
Black shale	7	81	Coal
Black slate	8	89	Measures.
(Sept. 3, down to 95'2', coal between 81 and 88 ft? Lighter fire clay at bottom).			
A little coal			
Black shale	12	101	
Sand rock	3	104	
Hard dry lime rock. Cl mod SO_4 mod.	9	113	Bayport, *i. e.*,
Sept. 5, Down to 118 ft., struck water in last 10 feet; the drillings full of brown angular fragments with some sulphide of iron and zinc, showing probably that they have passed through a siderite nodule.			Maxville.
Light lime rock (effervescing freely)	14	127	Limestone.
A drop of 7 in., SO_4 mod. Cl med. + Sp. gr. 1.002 +,			
Light and blue shale	50	177	
Sept. 9, sandy shale 7' below the drop, then blue shale 12 to 144 this day.			
Sept. 10, 145–155 blue calcareous shale.			
Sept. 11, 155-170 blue calcareous shale sticky.			
Work interrupted 12-13th.			
Sandrock	5	182	Michigan series.
Lime rock	6	188	
Sandy shale	10	198	
Light shale	8	206	
Dark lime rock	19	225	Soule beds.
Light shale	24	249	
Lime rock	3	252	
Water sand rock	48	300	Napoleon sandstone.
Fine sand rock	10	310	Upper Marshall.

Finished Friday, Oct. 2d, 1896. Good flow.

S. E. ¼ of N. W., on dividing line between Campbell and Martini's place, about 100 feet from the street.

1130 N., 1430 W. Cl med. SO_4 med. Hard. Sp. Wt. 1.004. Head fluctuates every day. In 1889, 10 foot head, Aug., 1896, 3 foot head, in Sept., 1896, 2 foot head. It failed entirely soon after. Martini and J. W. Campbell, owners. Depth 280 to 285 feet (330?). No flow until at the very bottom, then with one blow of the drill at least 10 feet head. A. T. 596.

675 N., 1265 W., Main street, opposite Fourth street. Flowing well T. 8° R. = 50° F. Depth 365 feet. Owned by Hæberlein's Brewery. This well is deeper than necessary for water, and they stopped going further for fear of getting salt. It is 5° less hard than Mosner's well and has less S. It is cased to 160 feet, then there is blue slate 20 feet, the rest is solid rock,—about 300 feet to sandstone. It is probable that the driller commenced getting into the red rock which other records show underlies the Napoleon, and is commonly taken to be a sign of salt. A. T. 607.

650 N., 1350 W. Block 11 W. C. Chappell's addition 400 ft. N. of 1-16 line and 50 feet west of center. Depth 275 feet. A. T. 600. Chappell's well.

This well is slightly salty, and used to flow, but the casing burst and the water leaked into the old mine. In Jan., 1898, the leak is said to have become so bad that the heads of all the other flowing wells dropped. It seems to be largely responsible for the drop of the head in the Napoleon.

1100 N., 1537 W. N. W. corner Union. Mosner's hotel. Flowing well, supplies 6 pipes. 3 or 4 foot head. Cl. med. T. 54° F. Depth 298 feet. An analysis lost showed Fe_2O_3 Na Cl., S, Mg., etc. A. T. 593.

1160 N., 1420 W., S. E. of N. W. Depth 304 to 307 feet. Owner, C. F. Bach. Drilled in December by C. Hofmeister. Sp. gr., 1.003, Cl med. SO_4 low. A. T. 597.

Flowed at first, but has ceased. They keep pumping it night and day by a wind mill.

750 N., 1800 W. N. W. of S. W., Depth 293 feet. Sebewaing Coal Co. A. T. 593.

Forms a white scale in boiler. Salt and iron evident.

1010 N., 1400 W. Cl med. SO_4 low. Depth 160 to 170 ft. A. T. 596 feet. Behind Likens' store.

700 W. and about 650 N. A. T. 610. Bach's well.

Used to flow but stopped when the Martini-Campbell well started.

About 1200 N., 1950 W., at Stave Mill. Depth 115 feet. A. T. 593. Liken and Bach, owners

490 N., 1460 W. A. T. 600.

Original coal exploration.

490 N., 1375 W. Depth 86 feet. A. T. 600.

Original shaft 86 feet to bottom of coal passing through boulders of sandstone.

On Chappell's land. Depth to rock 50 feet, total depth 112 ft. 3 in. A. T. 596. J. C. Liken's well No. 10. Record as follows:

	Thickness.	Depth.
Clay	50	
Sandstone	10	60
Hardpan and gravel	2	62
Sandstone	13	75
Light shale	7	82
Slate	23' 7"	105' 7"
Coal	4' 5"	110
Fireclay	2' 3"	112' 7"

Section 9.

1350 N., 1400 W. Depth 70 feet (120). A. T. 607.

Used to flow but has not flowed since 1889. It was later deepened in testing for coal, but we have no record of it; only a few inches of coal at most, were found.

50 N., 1900 W. Cl tr. SO_4 med. Depth 160 to 180 feet. A. T. 607. Driller J. C. Russell, for Graves. Cf. Sec. 1.

Section 10.

50 N., 1680 W. Depth 164 feet. Cl tr. SO_4 trace. A. T. 630.

This well is in blue stone not sandstone, but of a pale ash blue color. Water at 64 feet and rose to within 9 feet of surface at first, at 164 feet depth rose to within 7 feet of the surface. Now (1886) it is lower.

50 N., 1200 W. Depth to rock 60 feet, total depth 247 feet. Cl low. SO_4 0; at 150 feet water rose to within about 1 foot of surface. A. T. 622.

Mainly blue rock at bottom, 50-60 feet in sand rock.

50 N., 800 W. Cl med. SO_4 trace, stains of Fe. Depth 480 feet. A. T. 624.

Chas. Voltz, owner; Chas. Hofmeister, driller.

At 180 feet water, which at first rose to within 2 or 3 feet of surface. At 220 feet water again; got red rock after passing through sandstone at bottom.

1360 N., 460 W. Cl low. Depth to rock 80 feet, total depth 182 feet. At 140 feet in sandstone as much water as it ever got.

1350 N., 780 W. A. T. 625.

Section 11.

1780 N., 240 W. Cl trace. SO_4 strong. Depth 145 feet. A. T. 630.

1360 N., 2280 W. Cl low, SO_4 strong. Depth to rock 50 feet, total depth 172 feet. Water at 77 feet and rises to 18 feet below surface. This well is cased to rock and has white sandstone at the bottom. This well has two slightly different records, the one above was furnished at the house, the one below from J. Russell.

J. Russell, driller. Joseph Gruen, owner. A. T. 630.

August 28, 1885.

	Thickness.	Depth.
Red clay	9	
Blue clay	48	57
Hardpan and boulders	2	59
Sand and gravel	1	60
Slate or soap rock	4	64

Deepened June 30th 1886.

	Thickness.	Depth.
Hard dark rock	6	70
Slate rock	14	84
Hard dark rock	1	85
Slate rock	2	87
Hard dark sandrock	4	91
Black sandrock	5	96
Hard flint rock	2	98
Sandrock	18	116
Very hard rock	3	119
Sandrock (Napoleon)	51	170

50 N., 1240 W., Cl low, SO_4 strong. A. T. 630.

Depth 200 feet, about 80 feet of casing. E. Rievert, owner.

50 N., 820 W. Cl low. SO_4 med. Depth to rock about 70 feet, total depth 300. A. T. 630. D. H. Voltz, owner.

Sandstone at 70 feet, then a few feet of soap rock, then sandstone the rest of the way to 300 feet. (?)

50 N., 320 W., Cl low. SO_4 med. A. T. 630. Depth about 96 feet. This well is cased for 58 feet. Cost (50c a foot for first 50 feet, $1 a foot thereafter) + $29 for casing = $100. Caleb Voltz, owner. C. Hofmeister, driller.

120 N., 50 W. Cl low, SO_4 strong. Depth to rock 182 feet.

1240 N., 1950 W. Depth 60 feet. A. T. 630.

Water is said to have been struck just on top of rock, but the well is filled up. W. Kuehn, owner.

N. E. of N. W. ? A. T. 630. C. Finkbeiner, owner. J. Russell, driller. Aug. 18, 1895.

	Thickness.	Depth.
Red clay	14	
Blue clay	43	57
Hard pan	8	65
Slate or soaprock	9	74
Very hard lime and sandrock	20	94
Sandrock	16	110
Very hard rock	2	112
Water sandrock	16	128

Section 12.

1950 N., 1760 W. Depth 128 feet. A. T. 630.

1500 N., 50 W. Cl low, SO_4 trace. A. T. 630. Depth 90 feet.

680 N., 50 W. Depth 86 or 200 feet. A. T. 630.

Section 14.

1950 N., 1580 W. Cl trace, SO_4 strong. A. T. about 630. A. Voltz.

50 N., 1680 W. Cl trace, SO_4 med. A. T. about 632. Depth to rock 90, total depth 268 feet. At first in soaprock, then harder rock and sandstone.

50 N., 1360 W. Cl trace, SO_4 med. Depth to rock 80, total depth 296 feet. A. T. 632. This well is cased for 80 feet.

50 N., 700 W., Cl trace, SO_4 strong. Depth 150 feet. Bauer, owner. A. T. 632.

Section 15.

1850 N., 1950 W. Cl low SO_4 trace. Depth to rock 70 feet, 74 casing, total depth 216 feet. A. T. 620.

Riever and Studer's cider mill. C. Hofmeister, driller. From 69 to 80 feet this well passed through buff limestone, from 80 to 105 feet green calcareous shale. No coal was found, and it did not go down to sandstone.

When the water in this well is roily rain is expected in 24 hours.

1950 N., 200 W. Cl low, $SO_4$0, A. T. 625. Depth to rock 84 feet, total depth 200 feet. John Adams, owner. No more water than a second well has at 107 feet. About 4 feet in sandrock.

400 N., 1950 W. Total depth 135 feet. Cl low, SO_4 med. A. T. 622.

Water level 24 feet below surface. This well is cased for 100 feet, gas pipe is used for 70 feet.

670 N., 1950 W. Sp. Wt. 1.003, Cl low, SO_4 med. Ruppert and Sanders, owners. Drilled by J. Russell.

This well was 150 feet deep, afterwards deepened to 200 feet.

Section 16.

1950 N., 520 W. Cl low. Total depth 260 feet.

400 N., 50 W. Cl low, SO_4 med. A. T. 625. Depth to rock 73 feet, total depth 126 feet. There is said to be about 2 in. of coal in this well.

650 N., 50 W. Sp. Wt. 1.004 Cl strong, SO_4 trace. A. T. 624. Depth to rock 72 feet, total depth 350 feet. This well goes through sandrock to red paint rock. Soft water, which stood at first 4 ft. 3 in. below the surface afterwards fell to 20 feet below the surface.

Section 17.

W½ of N. W. ¼, on land of Henry Liken, Jr., Sebewaing. No. 3 test well for Saginaw Bay Coal Company. A. T. 600. Total depth 82 feet 1 inch. Record as follows:

	Thickness.	Depth.
Sand	3	
Clay	52	55
Hardpan	4	59
Hard sandrock	5	64
Light slate	13	77
Black slate	2	79
Coal	2' 10"	81' 10"
Reddish slate	3"	82' 1"

N. ½ of N. W. ¼, on Beck's land, Sebewaing. No. 2 test well for Saginaw Bay Coal Company. Total depth 84 feet. Record as follows: A. T. 600.

	Thickness.	Depth.
Clay	65	
Hardpan	7	72'
Black slate	8' 8"	80' 8
Sulphur and iron	8"	81' 4"
Coal	2'	83' 4"
Sandy fire clay	8"	84

S. E. ¼ of N. W. ¼ on Schilling's place. Records from J. C. Liken.

No. 1.

	Thickness.	Depth.
Clay	60	
Hardpan	7	67
Rotten shale	1½	68½
Slate	13	81½
Coal	4' 5"	85' 11"

No. 2.

	Thickness.	Depth.
Clay	62	
2 ft. gravel at 40 ft.		
68 ft. to sandstone.		
Sandstone	10	78
Shale	4	82
Slate	13	95
Coal	4' 7"	99' 7"

N. W. ¼. Sebewaing Mining Company. J. Russell, driller. Record as follows: (Note the greater depth to rock.)

	Thickness.	Depth.
Clay	59	
Hardpan	2	61
Sand and gravel	3	64
Hardpan	11	75
Large boulders	1½	76½
Slate and sand mixed	13½	90
Black slate	12' 1"	102' 1"
Coal	4' 2"	106' 3"
Rotten slate	1	107' 3"

Section 18.

900 N., 400 W. Sp. Gr. 1.005, Cl strong, SO_4 med. Depth 300 feet. A. T. 590. Record below. Well at the Saginaw Bay mine, record below by J. Russell.

	Thickness.	Depth.	
Sand	8		
Clay and dry quicksand	12	20	Pleistocene
Blue clay	28	48	
Boulders	5	53	
Sandrock	38	91	
Cave in of slate	21	112	Coal measures
Slate, soft	6	118	
Fireclay	6	124	
Sandrock	10	134	
Sand and slate mixed	70	204	
Dark limerock	24	228	Grand Rapids group
Soap limerock	2	230	
Hard limerock	12	242	
Hard sand rock	4	[illegible]	
Fine sand rock	[illegible]	[illegible]	Marshall
Slate rock		300	

N. E. ¼. A. T. 590.
No. 1 test well for Saginaw Bay Coal Co.

	Thickness.	Depth.
Sand	4	
Clay	55	59
Hardpan	6	65
Light slate	6	71
Sandy fireclay	15	86
Hard black rock	2	88
Sandy fireclay	19' 6"	107' 6"
Hard black rock	5' 6"	113
Water sandrock	1' 6"	114' 6"

1900 N., 1100 W. Cl strong, SO_4 med. Fe indications, Sp. Gr. 1.006. Depth 284 (384?) feet. This well has fine flow and stands on the edge of the old shore about 4 feet above lake.

1750 N., 100 W. Sp. Gr. 1.007, Cl strong, SO_4 med. T. 52° F. Depth to rock 52 feet, total depth 303 feet. 592 A. T.

This well had a strong flow 4 feet above ground, but the strength of flow varies with the weather. It was deepened 22 feet since first put down, which did not improve the flow.

	Thickness.	Depth.	
Clay	51		
Sand and gravel	1	52	
Loose sandrock	2	54	
Hard rock	2	56	
Dark sandrock	18	74	
Coal about	6 in.	74' 6"	
Sandrock	1' 6"	76	
Slate	6	82	
Coal	3' 8"	85' 8"	
Bottom slate	1' 4"	87	
Sandrock	13	100	
Light slate or sandy fireclay	96	196	Michigan
Hard dark rock	24	220	
Slate	20	240	
Hard lime rock	8	248	
Sand rock	55	303	Napoleon sandstone

About 16 feet east a well was put down for coal and found none where this found 3 ft. 8 in., see the following record:

	Thickness.	Depth
Clay	50	50
Hardpan	5	55
Sandrock	30	85
Coal	1	86
Clay	2	88
Sandrock	30	118
Shale	8	126' 6"

1750 N., 94 W. On the Lutz farm N. part of 18. J. C. Liken's farm. A. T. 590.

No. 5.

	Thickness.	Depth.
Clay	45	
Sandrock	21	66
Sticky blue shale	6	72
Slate	10	82
Coal	4' 4"	86' 4"
Fireclay	1' 6"	87' 10

No. 6 on same farm.

	Thickness.	Depth.
Clay	45	
Sandrock	5	50
Sand and gravel	20	70
Shale	3' 6"	73' 6"
Coal	2	75' 6"
Hardpan	2	78' 6"
Sandstone	21	100

No. 7 same farm.

	Thickness.	Depth.
Clay	43	
Sandstone	9	52
Shale and slate	10	63
Coal	1	63
Hardpan	8	71
Slate	8	79
Coal	3′ 2″	82′ 2″
Fireclay	1	83′ 2″
Sandstone	2′ 4″	85′ 6″

1300 N., 1000 W. No. 5 test well for Saginaw Bay Coal Co., on their own land. July, 1894. J. Russell, driller.

	Thickness.	Depth.
Sand	3	
Clay	39	42
Hardpan	3	45
Sand rock	26′ 4″	71′ 4″
Coal about	5″	71′ 9″
Sand rock	8	79′ 9″
Slate	6″	80′ 3″
Sand rock	7′ 1″	87′ 4″
Coal	4	91′ 4″
Light shale	3″	91′ 7″

N. E. ¼ of S. E. ¼. No. 4 test well for Saginaw Bay Coal Co., on land of B. Engelhard, Sebewaing.

	Thickness.	Depth.
Sand	4	
Clay	58	62
Hardpan and gravel	10	72
Sand and gravel	18	90
Slate	3	93
Coal	2′ 7″	95′ 7″
Bottom slate	5″	96

1050 N., 1000 W. No. 10. Depth to rock 45 feet, total depth 79 feet 7 inches. A. T. 586 (4.5 above datum). Record:

	Thickness.	Depth.
Clay	43	
Sand and gravel	2	45
Sandstone	15	60
Limestone	6″	60′ 6″
Sandstone	7′	67′ 6″
Slate	1	68′ 6″
Sandstone	6′ 6″	75
Slate	1	76
Coal	3′ 7″	79′ 7″

1060 N., 600 W. No. 9. Depth to rock 76 feet, total depth 90 feet 6 inches. A. T. 588 (6.3). Record:

	Thickness.	Depth.
Clay	45	
Sand and gravel	5	50
Hardpan	26	76
Slate	11	87
Coal	3′ 6″	90′ 6″

940 N., 0 W. No. 13. Depth to rock 64 feet, total depth 86 feet 5 inches. A. T. 598 (16.7). Record:

	Thickness.	Depth.
Clay	63	
Sand and gravel	1	64
Sandstone	17′ 4″	81′ 4″
Slate	1	82′ 4″
Coal	4′ 1″	86′ 6″

500 N., 750 W. No. 14. Total depth 163. A. T. 585 (12.6).

90 N., 1040 W. No. 12. Depth to rock 58 feet, total depth 118 feet. A. T. 592 (9.7). Record:

	Thickness.	Depth.
Clay	58	
Sandstone	42	100
Slate	14′ 3″	114′ 3″
Coal	3′ 9″	118

Section 20.

900 N., 1250 W. A. T. 620. Chas. Winter, owner.

	Thickness.	Depth.
Clay	74	
Sand and gravel	45	119
Fine sand rock	30	149
Lime and dark sand rock	67	216

Section 21.

900 N., 50 W., Cl med. +, SO_4 med. A. T. 620. Depth 180 feet +.

1460 N., 50 W., Cl low, SO_4 med. A. T. 620. Total depth 230.

980 N., 50 W., Cl low, SO_4 med. A. T. 620. Depth to rock 100 ft. Total depth 193 feet. This well has 4 in. casing for 60 feet, and 3 in. casing for 100 feet.

800 N., 1950 W. Cl strong, SO_4 strong. Sp. Wt. 1.003. A. T. 620. 80 feet to rock, total depth 367 feet.

This well is cased to rock. The water becomes more brackish after pumping. (Cathartic on harvesters unused to it.)

1950 N., 160 W. SO_4 low, Cl med. +, Sp. Wt. 1.002. Depth to rock 86 feet, total depth 270 feet.

At first the water in this well rose to within 18 feet of surface. The first rock is sandstone, 20 feet, then some coal, then soaprock, and then the sandstone whence the water came.

50 N., 420 W. Cl low, SO_4 med. A. T. 620. Depth to rock 72 feet, total depth 285 feet.

The water in this well rose to within 22 in. of the surface. This well has about 70 feet of white sandstone, Napoleon, at the bottom.

50 N., 1640 W. Cl 0, SO_4 med. A. T. 620 feet. Depth 100 feet +.

This well flowed at first, now the water stands 20 feet below the surface.

Section 22.

50 N., 300 W. Cl 0, SO_4 low. A. T. 630. Depth 168 feet. John Sting, owner.

300 N., 1100 W. A. T. 626. Depth to rock 66, total depth 105 feet.

This well had 66 feet of surface, of which the bottom, 35 feet, was "putty" clay, then 6 feet of hardpan, 1 foot as hard as emery, (?) about 6 in. limestone, with a spring between limestone and sandstone, then 32 feet sandstone and soaprock.

300 N., 1200 W. Cl trace, SO_4 med. A. T. 626. Depth to rock 70 feet, total depth 124. This well ends in 3 feet hard rock, then 3 ½ feet sandstone.

1240 N., 1800 W. Cl low, SO_4 low. A. T. 620. Depth to rock 60 feet, total depth about 200 feet. Shell rock hard as flint over the last 20 feet of sandstone, very little soap rock.

1460 N., 1950 W. Cl low, SO_4 med. A. T. 620. Total depth about 400 feet. A. Bach, owner.

Section 23.

1950 N., 1360 W. Cl trace, SO_4 med. A. T. 635. Total depth about 200 feet.

560 N., 1950 W. Cl 0, SO_4 med. A. T. about 635.

Section 26.

1300 N., 1950 W. Cl trace, SO_4 med. A. T. 632. Total depth 100. This well used to flow. All around this neighborhood it is 100 to 115 feet to water.

Section 27.

1950 N., 200 W. Cl 0, SO_4 med. A. T. 630. Depth to rock 60 feet, total depth 205 feet. This well is cased for 60 feet.

1950 N., 900 W., Cl trace, SO_4 med. +, A. T. 629. Depth to rock 74 feet, total depth 168 feet.

1400 N., 1950 W. Cl low, SO_4 low. A. T. 625. Total depth 140 feet. When the wind is from the west the water is said to be cloudy.

50 N., 540 W. A. T. 630. Total depth 95 feet. This well is not flowing.

Section 28.

1950 N., 700 W. Cl low, SO_4 med. Depth of casing 95 feet, total depth 227. A. T. 620.

1950 N., 100 W. Cl 0, SO_4 med.

200 N., 1950 W. Cl trace, SO_4 trace. Depth to rock 50 feet, (?) total depth 79. This well is in white sandstone and is cased for 50 feet.

740 N., 1950 W. Cl low, SO_4 low.

1740 N., 1950 W. Cl low, SO_4 med. Total depth 294 feet.

1120 N., 50 W. Old mill which had a drilled well.

Section 29.

1950 N., 260 W. SO_4 strong, Cl med. +, Sp. Wt. 1.003. Depth to rock 140 feet,(?) total depth 228 feet. A. T. about 620 feet. Water was struck at 200 feet. This well used to flow and is cased for 140 feet,—is evidently in the channel.

1800 N., 1950 W. Depth to rock 150 feet, total depth 260. Owner, F. Becker.

720 N., 1950 W. Sp. Wt. 1.008, Cl strong, SO_4 strong. A. T. 620. Depth to rock 140 feet, total depth 300 feet. Geo. Hofmeister. The water rose more than 10 feet above ground until the coal mines began to work. Good water was found at 180 to 200 feet, then became salty.

500 N., 1460 W. Cl low, SO_4 low. A. T. 620. Depth to rock 128 feet, total depth 266 feet. A. Armbruster, owner. This well was cased for 128 feet. Some coal was found in it but mostly hard rock or sandstone.

420 N., 50 W. Cl low, SO_4 low. A. T. 620. This well was cased for 67 feet and is 80 feet deep.

740 N., 50 W. Cl tr., SO_4 trace. A. T. 620. This well is 136 feet deep and a trace of coal was found in the sandstone.

1500 N., 50 W. Cl low +, SO_4 med. A. T. 620. Depth to rock 70 feet, total depth 105 feet.. This well "showed coal."

Section 30.

750 N., 150 W. A. T. 620. Owner, H. Irion; Chas. J. Hofmeister, Jr., driller. This well cost 50c a foot (5¢ off for cash), and 35c for casing.

The water is quite hard and can be lowered, by pumping, to 23 ft. below surface. It rose at first to 14 feet below surface, and is used for house and cattle.

RECORD FROM SAMPLES OF DRILLINGS.

	Feet.
Struck quicksand at	23
Blue clay	32 to 50
Quicksand and gravel	50 to 150
Rock at	150
Mainly sand (this is doubtless sand and the next is dolomite)	160 to 164
Impure sand, angular, dolomitic	164 to 166
Arenaceous dolomite, pyritiferous with speck of feldspar	166 to 180
Clean gray quartz, sandstone	188 to 191

350 N., 1000 W. Sp. Wt. 1.003, Cl med. +, SO_4 strong. Depth to rock 85 feet, total depth 202 feet. This well used to flow.

Section 31.

300 N., 1950 W. No. 1, Brackish. SO_4 strong. Sp. Wt. 1.007. Depth about 200 feet. No. 2, said to have been not salty originally. It is now stopped up. Depth about 150 feet.

Section 32.

640 N., 1950 W. Cl tr., SO_4 low. A. T. 620. Depth 150 feet. This well is cased for 120 feet.

1460 W., 1950 W. Cl low, SO_4 low. A. T. 620. Depth 165 to 175 feet, cased for 140 feet. The rock is said to be mainly hard stuff, probably limestone.

1400 N., 50 W. A. T. 620. Depth 125 feet.

1600 N., 50 W. A. T. 620. Depth to rock 64 feet, total depth 135 feet. This is a flowing well. T. 51½° F.

140 W., 50 N. Depth to rock 73 feet, total depth 118 feet. Strong flow five feet above ground.

Section 33.

1800 N., 880 W. Cl tr. SO_4 low. A. T. about 625. Depth to rock 73+ feet, total depth 105 feet. This well was at first drilled to 81 to 85 feet and afterwards deepened 20 feet. It was 8 feet in sandstone at first. Flowing well, T. 50½°.

1950 N., 1320 W. Cl low, SO_4 trace. Depth 105 feet. The temperature of flow is 52° F.

1780 N., 50 W. Depth 72 feet. A. T. 627 feet. This well is drilled and used to flow.

50 N., 200 W. Depth 72 feet. Water rose to within three feet of surface.

50 N., 720 W. Depth 64 feet. Water rose 4 feet above surface.

600 N., 1950 W. Depth 96 feet, cased 61 feet. Water tastes free from mineral.

800 N., 1950 W. Depth 126 feet.

Section 34.

50 N., 1160 W. Cl 0, SO_4. Fred Sting, owner. A. T. 629. This well was sunk 59 to 60 feet in quicksand, and the water rose 2 feet above ground. T. 54° F.

760 N., 50 W. Cl low, SO_4 med. Depth to rock 88 feet, total depth 205 feet. A. T. 632.

1120 N., 50 W. Cl low,— SO_4 med.— Depth 280 feet (?).

1720 N., 50 W. Cl trace, SO_4 trace. Depth to rock about 64 feet, total depth 188.

1900 N., 50 W. Cl trace, SO_4 trace. This well is 132 feet deep, cased to 58 feet. Water rose to 10 feet below surface. A. T. 632 feet.

50 N., 260 W. Cl trace, SO_4 low. A. T. 631. This well is more than 100 feet deep.

1700 N., 1950 W. A. T. 627. Depth of well 75 feet. This well used to flow.

The wells of this section are divided into two groups, one (a) drawing water from the subcarboniferous limestone at from 58 to 100 feet, the other (b) from the

Napoleon or Upper Marshall sandstone from 150 to 200 feet down. The latter pass through dolomitic shales of the Michigan Salt Group and these not being cased off give a somewhat gypsiferous water.

Section 35.

400 N., 1950 W. Depth to rock 80 feet, total depth 202 feet. A. T. 632. C. J. Hofmeister, driller, for Christ Deeg, owner.

900 N., 1950 W. A. T. 632. Depth to rock 62 feet, total depth 192 feet. Jacob Sting, owner. Cased two feet in rock and one foot above ground.

RECORD FROM SAMPLES.

Pleistocene	0 to 18	Hardpan.
	18 to 60	Blue clay.
	60 to 62	Gravel.
Upper Grand Rapids	62 to 66	Yellow dolomite.
	66 to 72	Greenish grey shale.
	72 to 80	Grey micaceous sandstone.
	80 to 85	
Michigan series or Lower Grand Rapids	85 to 90	Dolomitic. Shales somewhat pyritiferous and arenaceous, dull grey.
	96 to 100	
	100 to 105	
	112 to 120	
	120 to 125	Impure grey sandstone with some pyrite and calcareous matter.
	126 to 128	
	129 to 130	
Napoleon sandstone	130 to 132	White sandstone, clearest at 150-160 (glass sand).
	132 to 136	
	136 to 140	
	140 to 145	
	150 to 160	
	160 to 167	
	191 to 192	Somewhat impure calcareous sandstone.

Brookfield township (T. 15 N., R. 10 E. L.).

Section 1.

50 N., 540 W. Cl low, SO_4 med. A. T. 649. Total depth 62 feet.

Section 2.

1950 N., 660 W. A. T. 648. Total depth 185 feet.

Section 3.

1950 N., 1320 W. SO_4 low, Cl low. A. T. 645. Depth to rock 135 feet, total depth 235 feet. Fritz Matz, owner; driller, W. Smith. Mainly blue clay (sample taken). chips came from the boring at 130 feet.

Section 5.

1050 N., 1900 W. Cl low, SO_4 trace. A. T. 632. Frank Smith, owner. Depth 138 feet.

940 N., 1950 W. Cl low, SO_4 mod. Depth 122 feet. L. Wisner, owner; J. P. Russell, driller. Sept. 13, '95.

	Thickness.	Depth.	
Red clay	13	......	Pleistocene.
Blue clay	52	65	
Hardpan and boulders	8	73	
Sand and gravel	2	75	Grand Rapids group.
Shell slate	2	77	
Hard slate	12	89	
Soap rock	3	92	
Hard slate rock	6	98	
Dark sandrock	2	106	
Soap rock	2	108	
Hard dark sandrock	2	110	
Soft white rock (gypsum ?)	5	115	
Very hard sand rock	2'6"	117'6"	
Water sand rock	12'6"	130	

Section 6.

1000 N. W., along diagonal road, i. e., 707 N., 707 W. Trace SO_4, Ca low, Cl med., strong Fe taste. Depth to rock 64, total depth 165 feet.

Depth 127 feet. George Kundinger's well, Kilmanagh, P. O. drilled by J. Russell. July 15th, 1896.

DRILLER'S RECORD.

	Thickness.	Total.
Clay	55	55
Hardpan	3	58
Loose dark rock	4	62
Hard clay rock	4	62
Hard dark rock	5	67
Hard dark rock	6	73
Dark lime rock	25	98
Sandy fire clay..	4	102
Hard sand rock	4	106
Soft sand rock	21	127

1000 N., 1120 W. SO_4 medium, Ca medium, Cl strong trace. A. T. 632. Total depth 65 feet, a few feet in rock.

50 N., 1280 W. Cl low, SO_4 med. Depth to rock 65 feet, total depth 65 feet. Few feet in rock.

950 N., 1220 W. Cl trace, SO_4 strong. Total depth 65 to 70 feet.

Section 7.

1950 N., 1950 W. Cl trace, SO_4 med. A. T. 630. Total depth 76 feet.

1825 N., 1950 W. Total depth 100 feet.

N. W. of N. W. Total depth 140 feet. Cl low, SO_4 trace. Much less hard than the dug well. water came at 95 feet. 69 feet of casing, well extends about 20 feet in grey sandstone. Owner, A. Dreher.

680 N., 1700 W. Cl low, SO_4 trace. At about 80 feet first water was struck, it was cloudy and rose to five feet below surface and was very abundant. Owner, Carl Jahnke.

350 N., 1950 W. Cl trace, SO_4 med. Water at 80 feet. Total depth 99 feet. This well does not reach sand rock, but is in blue soap rock.

Section 8.

1000 N., 900 W., 1480 W. on diagonal road, trace SO_4, trace Ca, at Cole's saw mill. Cl low, Fe present. A. T. 640. This well has about 83 to 85 feet casing and is 160 to 165 feet deep.

Section 10.

SO_4 strong, Ca med., Cl low. A. T. 650. Owner, J. D. Durand. Depth to rock 41 feet, total 51. This well had a slight flow.

Section 11.

SO_4, light trace D. Ca trace, Cl low. A. T. 651. This well is at Owen's farm house and is 180 feet deep.

Section 13.

220 N., 50 W. Cl 0, SO_4 0 D. A. T. 676. Depth about 30 feet to rock, total 102½. The well passed through flintrock first and then mainly sandrock. There was about two feet of rock before striking water.

210 N., 40 E. A. T. 676. Depth about 64 feet. This well went about 64 feet in surface material before it came to sandrock. The wells are near by and belong to the same owner.

Section 14.

About 1900 N., 1400 W. Ca low, Cl low, SO_4 tr. A. T. 650. Depth 170 feet. Temperature 48°. This is a flowing well at saw mill, Owendale, but the pump is not working. Same data also apply to another well at saw mill.

2000 N., 1060 W. SO_4 trace, Ca low, Cl medium. A. T. 650. Well at hotel.

660 N., 950 W. Depth 45 feet. This well once flowed, and had 4 foot head.

280 N., 1050 W. Depth to rock 56 feet, total depth 70 feet. Owner, Mrs. Carver. This well is in hard and soft blue rock, and water rose close to the surface.

800 N., 950 W. A. T. 655. Depth to rock 38 feet, total depth 53 feet, McArthur's well.

700 N., 1050 W. A. T. 655. Depth to rock 40 feet, total depth 43 feet. Owner, S. Good. This well is in soft rock, chips were struck at about 15 ft. in boring well. The water is good for washing.

T. Davis' well has total depth of 107 ft. Water was struck at 70 feet.

Section 15.

200 N., 1050 W. Depth to rock 54 feet. Owner, J. Ross. This well flows, and has a five foot head.

50 N., 520 W. Depth 33 feet. A. T. 644. This well used to flow and had 1¼ foot head at first but stood just at the surface in the fall of 1897. The water is hard. Owner, F. Carson.

N. W. part Shufeldt's. Flowing well.

800 N., 900 W. Total depth 60 feet. Flow with one foot head. T. Welch. Struck in gravel.

Section 21.

J. Finkel's well 60 feet deep, struck in gravel the water.

Section 22.

1950 N., 260 W. A. McKenzie's well. Dug 10 and bored 40 more feet, flows. Ca medium.

Section 23.

1250 N., 1900 W. Total depth 60 feet. Taylor's well, flows, in drilling were black lumps like coal.

1160 N., 1000 W. Depth to rock 47 feet, total depth 51 feet. Sandstone water. This is a drilled well. A. T. 613.

Section 24.

0 N., 120 W., Sandstone water. This is a drilled well.

Section 26.

720 N., 720 W. This well was hand drilled and used to flow.

1180 N., 1000 W. Depth to rock 50 feet, total depth 65 feet. A. T. 670.

This well is in sandstone, the pipe was cut three feet below level to get flow.

680 N., 1000 W. A. T. 675. Trace SO_4, tr + Ca and Cl Depth to rock 58 feet, total 62 feet.

This well is on the west side of the road. It used to flow but stopped in 1894.

Section 27.

900 N., 1000 W. A. T. 650. Total depth about 60 feet. This is sandstone water. T. 51° F., the pipe is exposed to the sun for 4 feet.

Section 33.

50 N., 50 W. A. T. 656. Baird and Prestage's sawmill. There are three wells on this farm and they all flow. (1.)Depth to rock 40 feet, total depth 90 feet. (2.) Depth to rock 40 feet, total depth 44 feet. (3.) Depth to rock 40 feet, total depth 48 feet.

Section 34.

50 N., 400 W. A. T. 655. Depth to rock about 30 feet, total depth about 60 feet. This well used to flow.

50 N., 1780 W. Depth to rock 40 feet, total depth 60 feet. This well used to flow with a six foot head but was checked.

2000 N., 1000 W. A. T. 658. This is sandstone water and has traces of Ca, Cl and SO_4. T. 50° F.

Section 35.

260 N., 1000 W. A. T. 692. This well was drilled in sandstone, the depth is unknown. The water has traces of Ca, Cl and SO_4.

Section 36.

1000 N., 860 W. A. T. 710. This well is in sandstone water. This is a drilled well on top of gravel beach.

1950 N., 1300 W. A. T. 693. This well was drilled near the front of a dissected terrace of gravel and sand and had only a little oily water.

Grant Township (T. 15 N., R. 11 E.).

Section 1.

1200 N., 2000 W. Total depth 13 feet. This is a surface well and there is plenty of water in the hollow. A. T. 782 feet.

S. W. of S. E. Total depth about 45 feet.

10 N., 50 W. Cl low, Ca low, SO_4 0. Depth to rock 85½ feet, total depth 86½ feet. A. T. 697. There is ½ foot of bluish rock at the bottom. The water rose to five feet from surface.

Section 6.

50 N., 50 W. Total depth 46 feet. A. T. 660 feet. This well was bored.

50 N., 1280 W. Total depth 11 feet. A. T. 660.

Near N. E. corner. A. T. 650.

Lead is said to have been found at 65 feet, but I doubt it. Cf. Henning's explorations there later. This shows the rumor on which he probably went. Chas. Henning's explorations were on E. ½ of N. E. ¼, first in slate.

1400 N., 1950 W. These are surface wells.

80 N., 1950 W. A. T. 650. Total depth 20 feet. This is a surface well.

Section 7.

220 N., 1950 W. A. T. 660. Depth to rock 35 feet, total depth 36½ feet. This well is in sandstone. The water contains traces of SO_4, Ca and Cl George Zimiker, owner.

A. T. 608. Jay M. Burgess, owner. Depth to rock 42 to 52 feet, total depth about 70 feet. Water was struck in this well at about 45 to 50 feet and flowed eight gallons an hour, but has since decreased and nearly stops flowing during northerly or northeasterly winds.

Shodwell and others say this well has not reached rock.

Section 8.

50 N., 1300 W. Depth to rock 60 feet, total depth 70 feet. A. T. 710. This well is in white sandstone. J. King, owner.

Section 11.

50 N., 860 W. Depth to rock 59 to 60 feet, total depth 120 feet. A. T. 730.

Aaron Endersby, owner. The water in this well stands about 15 feet below ground. The well is cased 43 feet 3 inches through quicksand, then 16 feet 2 inches more casing and below this is a bluish whetstone.

Around the N. W. corner of this section wells are about 8 to 11 feet deep.

Section 13.

N. E. ¼. Total depth 35 feet. A. T. 762. This well is probably not to rock. D. McPhail, owner.

Section 16.

300 N., 50 W. SO_4 low, Ca low, Cl none. Depth to rock 60 feet (40 or 100 feet ?) total, 210 feet. A. T. 647. The water rose to 4 feet below surface, and is sometimes muddy. The following record is from memory by J. H. Hare:

60 feet surface.

At 60 feet, fine flow of water, but in quicksand.

40 feet, sandstone.

40 feet, limestone hard and disturbed. The balance is grey grindstone with last ten feet in a soft sandstone holding a fine second vein of water.

Section 17.

1160 N., 50 W. 57 feet to rock, total depth 73 feet. Mrs. P. Walsh, owner. (Put down in Oct., 1897.) Record as follows:

Clay	15	
Quicksand	20	35
Till, "red clay, gravelly clay and hardpan"	22	57
White sand, soft rock	4	61
White flint	1½	62½
"Blue liquid paint rock," i. e, soft clay shale	1½	64
Hardrock	9	73

In some respects this agrees with a section into the Bayport limestone.

Section 18.

320 N., 1950 W. Cl 0, SO_4 0. Depth to rock 62 feet, total depth 126 feet. A. T. 670. This well is mostly through sandrock. There is said to be 3½ feet of "zinc" (?). Miles King of Elmwood, driller.

1950 N., 680 W. Cl 0, SO_4 0. A. T. 670. This well was newly drilled in 1896, apparently all through sandstone.

Section 22.

0 N., 1380 W. Ca. med., Cl low, D. A. T. 722. Total depth 50 feet. This is a clay water and comes up to the surface, through hardpan 3 or 4 feet deep.

Section 35.

2000 N., 940 W. Total depth 60 feet. This is a drilled well, some distance into rock. Wells in this vicinity are bored in several cases to about 35 feet depth in clay and gravel, but not to rock.

Sheridan Township (T. 15 N., R. 12 E.).

In a large part of this township wells are not in rock as there are numerous water-bearing gravels.

Section 1.

1740 N., 50 W. Depth 12 feet. Shallow like all around here. A. T. 762.

Section 3.

300 N., 1950 W. Depth 16 feet, plenty of water. A. T. 762.

Section 6.

550 N., 1800 W. Depth 20 feet through gravel, etc. Abundant water. A. T. 764. Another well was dug 12 feet through gravel and bored 35 feet.

Section 8.

1500 N., 1800 W. A. T. 700. Wells around here are surface wells at 12 to 20 feet deep.

Section 9.

1380 N., 50 W. Depth 24 feet through gravelly clay. A. T. 762.

Section 10.

580 N., 1850 W. Depth 27 feet on sandy ridge 200 feet broad. A. T. 770.

Section 13.

1720 N., 50 W. Depth 200 feet. A. T. 778.

120 N., 50 W. Depth to rock 30 feet. This well was dug 15 feet and drilled 8 feet. It flowed too much and they stopped it up. A. T. 780.

1720 N., 0 W. Depth to rock 24 feet, total depth 54 feet. Ca low, Cl low, SO_4 trace. Rock, blue sandstone. Sandstone varies from surface to 25 feet below surface in this neighborhood. A. T. 770.

Section 24.

540 N., 50 W. Depth 43 feet, 18 feet dug, the rest drilled. A. T. 796.

Section 25.

S. W. ¼. A. T. 780. Depth to rock 102 feet, (?) total depth 102 feet.

Section 35.

0 N., 780 W. Depth to rock less than 73 feet, total depth 73 feet. Ca trace, Cl slight trace. A. T. 791. This well is some distance in rock.

Section 36.

1600 N., 50 W. Total depth 52 feet. Bored but not to rock.

500 N., 150 W. SO_4 none, Ca trace, Cl slight trace. Depth to rock 60 feet, total depth 93 feet. A. T. 761. This well is 24 rods west of road, the rock is very hard for 3 or 4 feet, then very soft for the rest of the way. B. Morrison, owner.

800 W. 0. N., A. T. 843 feet. Depth to rock 90 feet, total depth 144 feet. This well is mostly through sandstone but there is some "soapstone" (shale) at the bottom.

Bingham Township (T. 15 N., R. 13 E.).

"Toward Ubly it is hilly and the wells are 100 feet deep on the hills."

Section 2.

1900 W., 300 N. Depth to rock 86 feet, total depth 91 feet. A. T. 844.

The water rises to 30 feet below the surface and this corresponds to the difference of level between this and Harrison's well on Sec. 3, T. 15, R. 13.

E. half of S. E. quarter. Depth to rock 130 or 135 feet, total depth 140 to 141 feet. A. T. 879.

The water rises 81 feet and is pumped 60 feet with force pump. T. Rapson, driller; Richard Harrison, owner. Record as follows:

Hardpan	20	
Blue clay	60	80
Mainly quicksand	50	130
Coarse sandstone	10	140

1420 N., 50 W.

50 N., 50 W. A. T. 824. Depth about 25 feet.

Section 8.

School house well 85 to 108 feet deep. A. T. 780. Most wells around here are 115 feet deep.

Section 9.

0 N., 800 W. Depth to rock 90 feet, total depth 95 ft. A. T. 831. This is a drilled well.

Section 10.

On the S. E. quarter of the N. E. quarter is a driven well.

1950 N., 880 W. A. T. 862 feet. Depth to rock 106, total depth 112. The water rises to 65 feet from top. If the water has the same head as at Harrison's 3-15-13, this well has about equal elevation, and this appears to be the case.

Section 16.

2000 N. A. T. 859. Depth to rock 100 feet, total depth 124 feet. John Wilson, owner.

Section 17.

0 N., 1900 W. A. T. 802. Depth to rock probably 73 feet, total 80 feet. This well was drilled.

Section 18.

1120 N., 1900 W. 782 A. T. Not 18 feet deep. Richard Nugent, near a marked rise in the road.

560 N., 2000 W. A. T. 774. Depth to rock 25 feet, total depth 35 feet. Samuel Donaldson, owner. The water rose to within two or three feet of the top.

Section 19.

2000 N., 1260 W. A. T. 770. Depth 28 feet to rock through gravel.

1360 N., 1950 W. A. T. 772. Depth 25 feet to rock.

Section 20.

0 N., 520 W. A. T. 864. Depth to rock 110 feet, total depth 115 feet. Owner, J. Hagen.

0 N., 1240 W. A. T. 864. Depth to rock about 100 feet, total depth 150 feet. James Richardson, owner.

Section 21.

2000 N., 1520 W. A. T. 820. Total depth 115. This well is 20 rods south of road in rock of unknown depth.

Section 23.

0 N., 1340 W. A. T. 800. SO$_4$ none, Cl none, Ca very low, Fe perceptible to taste. Depth to rock about 30 feet, total depth 70 feet. Owner, Geo. Baskin.

Section 29.

2000 N., 940 W. A. T. 863. Depth to rock 100 feet, total depth 150 feet. John Wurm, owner. This well is through clay to rock.

1000 N., 2000 W. A. T. 860. Depth to rock 90 feet, total depth 130 feet. Thomas Richardson, owner. This well is a quarter of a mile south of the north and south road.

600 N., 1900 W. Depth to rock 120 feet, total depth 140 feet. A. T. about 860. R. Richardson, owner.

Section 30.

1250 N., 30 W. Depth to rock 100 feet, total depth 130 feet. Robert Donaldson, owner.

Section 31.

500 N., 1300 W. Depth to rock about [illegible] feet, total depth [illegible] feet. This well is 50 rods east of road. A. T. 865.

1300 N., 1360 W. Not to rock though [illegible] feet deep. A. T. [illegible].

300 N., 1360 W. Total depth 100 feet, probably just to the bed rock.

Paris Township (T. 15 N., R. 14 E. D.).

Section 1.

400 E., 50 N. of S. W. corner. A. T. [illegible]. Total depth [illegible] feet. This well is through sandstone and conglomerate and not noticeably salty.

Sections 7 and 8.

2000 N., near quarter post between the sections. A. T. [illegible]. Depth to rock 30 feet, total depth 80 feet. This well is drilled through sandstone.

Section 11.

[illegible] W., 200 N. S. E. corner. A. T. [illegible]. John Smith, owner. Depth to rock 40 feet, total depth 70 feet. The water is bad and is said to be black. A well used to flow in this neighborhood.

Section 12.

800 S., 200 E. N. W. corner. A. T. [illegible]. Depth to rock 80 feet. Thomas Loch, owner. This well is bored through 8 feet of sandstone and the water is not noticeably salty.

Section 13.

100 N., 50 W. A. T. 766. Depth to rock 60 feet, total depth 68 feet. The water is salty.

Section 16.

720 W., 140 S., N. E. corner. A. T. 800. Depth to rock 65 feet, total 95 feet. This well was in 1896 being drilled through sandstone and shale, and they have not found water yet. John Oborski, owner.

1½ mile E. of S. E. corner of section 7. No rock or water found. Depth 172 feet (the same well?).

Section 20.

1020 W., 2000 N. SO_4 low, Ca low, Cl strong (brackish). Depth to rock 103 feet, total depth 168 feet. Owner, Arch. Curry.

Section 23.

1990 N., 1990 W. Cl. med.. H_2S present also. A. T. 784. Depth to rock 80 feet, total depth 150 feet. The water has a nasty sweet taste (from decomposing pyrite?).

Section 24.

1990 N., 1300 W. A. T. 790. This is a mineral well.

Section 26.

At hotel N. W. corner. Depth to rock 90 feet, total depth 93 feet. A. T. 712. Owner, Zuiger.

Section 29.

1380 W., 2000 N. Depth to rock 100 feet, total depth 117 feet. A. T. 840. Chas. McMillan, owner. This well furnishes a good supply of sandstone water.

Section 32.

0 N., 1240 W. Total depth 20 feet, just to rock?. A. T. 795.

Section 34.

S. W. quarter. Depth to rock 110 feet, total depth 114 feet. A. T. 880. Owner, W. Wilson. This well is through sandstone.

Section 36.

The general range of rock wells here is from 40 to 70 feet.

Sherman Township (T. 15 N., R. 15 E.).

Section 7.

"Good water" occurs in gravel wells twenty feet deep on gravel ridges of the Forest Beach. A. T. 756.

Section 12.

420 N., 140 E. Total depth 70 feet, depth to rock 54 feet. A. T. 680. 16 feet through shale. There is not much water in this well and it is salty. Martin Hoeldke, owner.

Section 30.

S. E. quarter. Total depth 47 feet, depth to rock 40 feet. This well is through sandstone and the water rose to surface. Hipps, owner.

N. E. quarter. Total depth 162 feet, depth to rock 114 feet. A. T. 790. Witwer's Cheese Factory. This well is through shale.

Section 31.

N. E. quarter. Depth to rock 55 feet, total depth 114 feet. A. T. 790. The water in this well is very little salty.

Section 32.

N. W. ¼, N. W. ¼. Depth to rock 60 feet, total depth 64 feet. A. T. 780. Owner, Hanselman. This well is through shale and the water is salty.

White Rock Township (T. 15 N., R. 16 E).

Section 6.

900 N., 50 W. A. T. 610. Total depth 24 feet. This is a dug well.

Section 29.

1100 W., 800 N. A. T. 590. Total depth 566 feet. Owners Thomson and Bro. This well is abandoned. See brine analysis in Chap. VI, § 4.

600 N., 110 W. A. T. about 590 feet. Owner, W. Thomson and Bro. Total depth 1311. See above.

The exact records of the above two wells cannot be disentangled, for the works are abandoned and the references to them do not serve to distinguish them. As Dr. Rominger saw samples down to 700 feet the record may be relied upon down that far.* In his report the depth of one well is variously given as 555, 566, and 565 feet and the other deeper one of which he saw the samples he reports as 700 feet in depth. It was probably deepened later, for a note of Wright gives a record to 1311 feet, whence we may derive the following column:

From 1 to 495 (Rom. about 450) blue shales with pyritiferous sandy streaks.

From 495 to 555 (Rominger about 100 feet of porous gray sandrock) strong and pure brine, as analyzed, 90% at 45° F. (or according to Garrigues in Rom. III, 184, 78.5°) brown sandrock, the Berea sandrock.

From 555 to 700 (Rominger reports only blue shales. According to Wright.

From 555 to 1311 are alternating strata of blue shale and limestone, shale predominating 20 to 1. From 600 to 610 feet down a three foot stratum of gaseous black shale was found, which is in the right place for the Cleveland shale. (See Chap. II, § 3). The drill must have gone into the Traverse (Hamilton) group, but probably not through it or the change would have been noticed. Besides according to the record of the Harbor Beach well it is not due. The chances are that this well stopped at the same belt of "extremely hard rock." found at 1,400 ft. at Harbor Beach, and at 153 feet in an Alpena well, which may be the Encrinal limestone.

Fairhaven Township (T. 16 N., R. 9 E.).

Section 1.

1340 N., 50 W. Total depth, just to rock, 7 feet. A. T. 622.

1000 N., 50 W. Total depth 30 feet. SO_4 and Cl low. A. T. 622.

It is 12 feet to rock in this well and water was struck at 13 feet which rises just to the surface. On top of the water was a hard scale (limestone) then a 6 in. cavity and grindstone below.

620 N., 50 W. Total depth 33 feet, depth to rock 11 feet. A. T. 622.

The first 11 feet of this well was dug, the rest was drilled. The well flows every spring.

50 N., 140 W. A. T. 612. This well is 50 or 60 feet deep and into rock.

Section 10.

50 N., 50 W. Total depth 150 feet. A. T. 590. Owner, J. D. Weeks. This is a flowing well and is salty.

Near mouth of Shebeon. Total depth 130 feet, cased for 31 feet, according to W. Hartmann, driller. This well was drilled mostly through soft grey rock, with an occasional four or five inch seam of hard stuff, e. g., at 128½ feet, but the driller already felt the springiness of the water underneath and urged him to go on. When struck water rose to the surface in ½ a minute.

Section 11.

30 N., 2300 W. Depth 40 to 45 feet. This well used to flow at first, according to Bullock the following was passed through:

Limestone, 12 feet; Blue rock, pyritiferous zone struck at 17 feet here, at 25 feet on Sec. 14.

Section 12.

1900 N., 2400 W. Cl low, SO_4 low. Depth to rock 63 feet, total depth 64 feet. A. T. 622. This well was sunk 48 feet 4 inches before reaching rock, then 30 inches rock (boulder) 24 feet quicksand, 1 foot limerock.

1660 N., 50 W. Depth to rock 30 or 36 feet, total depth 36 to 40 feet. A. T. 600. H. Dewing, owner. Pump used.

50 N., 50 W. A. T. 612. Depth to rock 11 feet, total depth 33 feet. Analyst, D. Fall of Albion, 0.06 Cl per thousand.

Section 13.

50 N., 900 W. Depth to rock 42 feet, total depth 50 feet. A. T. 618. Flowing with 2½ feet head.

50 N., 900 W. Depth to rock 48 feet, total depth 56 feet. A. T. 618. Flowing well with 2 feet head. SO_4 med. Sp. Wt. 1.002.

	Thickness.	Total.
Clay and gravel	22	22
Rock	2	24
Blue clay	28	52
Limestone	4	56

500 N., 50 W. Depth to rock 40 feet. Total variously reported as 130, 160, or 185 feet. A. T. 622. H. Rather, owner, well at barn.

SO_4 very strong, Cl str., Ca str. Sp. Wt. 1.004. Mr. Webber sent for this water to Bay Port for a cathartic. Dr. J. W. Campbell reports it to have a powerful cathartic effect on cattle. Analysis by Prof. Delos Fall of Albion. 0.323 parts Cl per thousand.

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*III, pp. 76-77, 184, 86.

(2) At house—

Depth to rock 40 feet, total depth 50 feet. SO_4 not so strong as in well No. 1, Sp. Wt. 1.002. Water rises to 1½ feet from surface.

860 N., 720 W. 47 feet casing and 47 feet deep. A. T. 616. Temp. of flow 51½°, Cl 0.

620 N., 700 W. A. T. 616. Well at barn, Temperature of flow 50°, about 3 feet head. Total depth 45 feet.

1160 N., 50 W. This is 35 feet deep and drilled. A. T. 621; Cl low, SO_4 low. Water about 1 foot from top.

1700 N., $SO_4$0. Total depth 30 feet. A. T. 620 feet. Temperature of flow 49° F. About 6 in. above ground.

Section 14.

W. half of N. E. quarter on Tom Snell's 80. D. Bullock, driller. This well was down 7 feet at 9 A. M. Thursday, June 11, and down 18 feet on Friday.

1980 N., 912 W. Depth 45 feet. It is said that lead was struck in this well. Calcareous fossiliferous sandstone is the surface rock; a darker limestone comes next underneath, then under that from 30 to 45 feet is blue shale with more or less pyrite, and the galena (?) The chances are that if struck this was a mere nodule in the shale.

Section 15.

280 N., 360 W. Depth 33 feet to rock, 107 total. A. T. 597. Collison's well. Land now owned by J. G. Tarry. D. Bullock, driller, July 15, 1896. Rock was struck at 31 feet, then blue shale with cubes of pyrite, at about 51 to 52 feet 7 to 8 ft. bed of gypsum. At 65 ft. a bed of pyrite. July 21 report with samples.

0 to 33 feet hard white clay, cased 37 feet.
35 to 40, gray rock (argillaceous limestone free eff.).
40 to 45, gray rock with pyrite and galena at 45 gypsum in large flakes. (?)
45 to 60, said to be gypsum. Bullock says only 7 ft. of gypsum.
60 to 65, pyritiferous shale with galena.
69 to 73, shale.
73 to 85, very pyritiferous.
85 to 107 fine grained dark sandrock. At 89 feet the water rose to within 6 feet of surface. It flows from the bottom, Sp. Wt. 1.005, SO_4 strong.

100 N., 1260 W. Depth to rock 25 to 30 feet, total depth 50 feet. Water rises to six feet of surface. At 35 to 40 feet there is said to be lead.

Section 21.

50 N., 320 W. A. T. about 597. This well is 18 feet deep. In surface deposits. George Schack is said to have found a piece of galena in digging this well.

Section 22.

1980 N., 600 W. Depth to rock 33 feet, total depth 60 feet. A. T. 597. Sp. gr. 1.005, SO_4 strong. This well is in shale and soapstone and has a pyrite galena vein between 40 and 50 feet.(?)

1800 N., 800 W. Depth 63 feet. A. T. 597. The water in this well rises to 6 feet from surface, but does not stand pumping.

(S. W. of S. W.) 100 N., 1900 W. Temperature of flow 51½°. A. T. 597. D. Bullock's record as follows:

0-52, surface.
52-58, soap rock, etc.
75, mineral, pyrite and galena.
110-130, brown sandrock, then white sandrock following.

They say at the house they have but 52 feet casing. They stop in white gypsum rock and show samples of gypsum. SO_4 tr., Cl low.

50 N., 1560 W. A. T. 597. This is a surface well.

450 N., 1450 W. Depth 50 to 70 feet. A. T. 597. Well at schoolhouse. "Flow about 1½ feet above the surface, in the winter and spring gradually growing less. A north wind increased the flow and an east wind diminished it." Geo. Kleaber.

Section 23.

N. E. of S. E. 50 W. This well was sunk to rock.

1950 N., 50 W. Total depth 12 feet. A. T. 608.

50 N., 400 W. Cl low, SO_4 str. Total depth 135 feet. A. T. 612. Water rises to 8 feet from surface. Mrs. Estman, owner.

100 N., 100 W. Depth to rock 50 feet, total depth 140 feet. A. T. 615. Jacob Brown, owner. This well is said to have four feet of black coal, cf. Weiser's well on Sec. 26.

Section 24.

1950 N., 900 W. A. T. 620. Total depth 55 feet. The water rose to within 20 inches of the ground.

1950 N., 800 W. Depth to rock 40 feet, total 49. A. T. 620. Water rises to the surface.

1950 N., 1740 W. A. T. 618. Depth to rock 7 to 8 feet, total depth 48 feet.
480 N., 50 W. A. T. 624. This is a shallow surface well.
820 N., 50 W. A. T. 623. This is a shallow surface well, not drilled.
1280 N., 50 W. Total depth 18 feet. A. T. 618. This well was dug in summer of 1895.
1620 N., 50 W. Total depth 7 feet. A. T. 618. There is said to be a spring on the east side of the place.
In W. ½ of N. W. ¼ of 24.
50 N., 1900 W. Depth 8 feet.

Section 25.

N. E. of N. W. 1900 N., Cl low, SO_4 strong. Total depth 78 feet. A. T. 622. Anton Adams, owner.
1600 N., 1950 W. SO_4 strong. A. T. 620. Anton Adams, owner. This well is drilled.
1260 N., 1950 W. Cl trace, SO_4 strong. Total depth 85 feet. A. T. 622.
50 N., 1840 W. Cl low, SO_4 low. Depth to rock 166. A. T. 626. Owner, J. Finkbeiner. This well was drilled 12 years ago in hard rock.
340 N., 50 W. Cl 0, SO_4 strong. Depth to rock about 80 feet, total depth 175 feet. A. T. 624. Owner, Buschlein. Rock was found at 40 or 50 feet, but it shaled off.
680 N., 50 W. Cl low, SO_4 strong. Depth about 180 feet.

Section 26.

400 N., 1950 W. Depth to rock 60 feet. A. T. 610. Owner, Wm. Henry.
1950 N., 400 W. Cl low, SO_4 strong. Casing 48 feet, 100 deep. A. T. 612. Carl Weiser, owner. Blue slate (with four feet of black) at 50 feet.
1900 N., 100 W. Depth to rock 50 feet, total depth 148 feet. A. T. 620. Owner, L. Engler.
1360 N., 50 W. Total depth 10 feet. A. T. 620. This is a surface well.
900 N., 50 W. Cl low, SO_4 strong. Total depth about 92 feet. A. T. 622. George Davis, hand drilled.
540 N., 50 W. Cl low, SO_4 strong. A. T. 626. Depth to rock 66 feet, total depth 102.
50 N., 660 W. Total depth 8 feet. A. T. 620 feet. Six feet of clay and two feet of water bearing sand.
(2) Total depth 18 feet.

Section 27.

1950 N., 760 W. A. T. 610. This is a surface well.

Section 28.

1950 N., 520 W. Depth to rock 60 feet, total depth 100 feet. A. T 530. Temperature of flow 51½° F. E. Rose, owner. W. Smith, driller. There is over 40 feet of casing to a big boulder, then small casing to rock at 60 feet. The mixed drillings show pyritiferous shale and limestone.

Section 33.

1701 N., 100 W. Cl med. Depth to rock 46 feet, total depth 175 feet. A. T. 600. Owner, Mrs. Schuch. Chas. Hofmeister, driller. Record from samples:

	From	To
Brown dolomite	48	52
Blue shale	62	68
Sandstone	148	175

640 N., 940 W. Total depth 14 feet. A. T. 609.
1400 N., 1800 W. Cl med., SO_4 low. Depth to rock 51 feet, total depth 205 feet. A. T. 610. Owner, J. Haffner; driller, Bullock.

	From	To
Blue shale looks like a good clay	53	85
Dolomite and shale	85	100
Blue shale	100	117
Impure pyritiferous limestone	117	124
Pyritiferous limestone	125	132
White sandstone with pyrite, Napoleon sandstone	133	205

Section 35.

50 N., 1900 W. A. T. 630. Cl low. SO_4 trace. Depth to rock about 80 feet, total depth 116 feet. Sample at 75 feet was pyritiferous shale. Driller's record:

	Thickness.	Total.
Clay surface	60	
Loose lime rock	5	65
Soap rock (i. e., calcareous shale with pyrite)	23	88
Very hard dark rock	4	92
Sandrock	24	116

1640 N., 1950 W. SO_4 low, Cl low. Casing 64 feet. Total depth about 150 feet. A. T. 612. Owner, August Rehbein. Record by J. Russell:

	Thickness.	Total.
Clay	49	
Hardpan	5	54
Dark lime rock	6	60
Slate rock	2	62
Lime rock	2	64
Soap rock	16	80
Hard lime rock	2	82
Slate rock	7	89
Hard sand rock	3	92
Fine sand rock	26	118
Dark lime rock	4	122
White sand rock (Napoleon)	21	143

Section 36.

1440 N., 50 W. A. T. 630. SO_4 low, Cl low. Depth to rock 60 feet, total depth 154 feet. S. Stahl, owner, of Bay Port.

50 N., 1760 W. Cl low, SO_4 strong. Depth to rock 50 to 55 feet, 80 to 90 feet of casing, total depth 136 feet. A. T. 630. This well passed through various kinds of rock, mainly soap rock.

50 N., 700 W. Depth to rock 70 feet, total depth 200 feet. A. T. 630. This water is not salty and rose to 18 feet below surface.

Winsor Township (T. 16 N., R. 10 E.).

Section 1.

1950 N., 1320 W. Depth to rock 30 feet. A. T. 633. Water rose to about 6 feet from the ground.

1950 N., 1040 W. A. T. 635. (1) This well was dug for 12 feet and is not cased. The water rises to the top. SO_4 low.

(2) Depth to rock 60 feet. This well used to flow, but is now stopped up.

1950 N., 400 W. Depth 40 feet, through gravel. A. T. 637. Water rose to within 6 feet of the top.

60 N., 50 W. SO_4 low, Cl med. Depth to rock 40 feet, total depth 40 ft. This is a dug well.

360 N., 1950 W. SO_4 low. Cl low. Total depth about 47 feet. A. T. 635.

860 N., 1950 W. SO_4 low. Total depth 32 feet. A. T. 634. This well was dug 8 feet, then drilled in gravelly clay and about 6 in. in black slate. This well is not flowing now.

1060 N., 1950 W. Depth to rock 30 feet. A. T. 633. This well flowed fast 3 or 4 years ago, it now stands about one foot from ground. When this well was dug the one above, just south, stopped flowing.

1200 N., 1950 W. A. T. 633. Depth to rock 30 feet, total depth 30 feet. The water in this well stands two feet from the surface and the well passes through sand, clay, gravel and at the bottom fine sandy bluestone.

S. E. quarter of N. W. quarter. A. T. 639. This well used to flow a ½ in. stream, but has now gone down to 3 feet from the surface. SO_4 low, Cl low. Total depth 41 feet. The water comes from a soapstone. (A windmill was put in 3 or 4 years ago and I suspect is partly to blame for the other wells not flowing.)

Section 2.

(Pigeon.) Wells from 29 to 40 feet deep used to flow. The surface water and water generally is hard.

160 N., 1287 W. Depth to rock 43 feet, total depth 90 feet. A. T. 630. H. Moeller, owner; W. Smith, driller.

The first rock was coarse, impure pyritiferous sandstone, then bluish arenaceous shale at 48 feet, then a mixture of fine sand, black shale, pyrite, etc.

50 N., 1075 W. Total depth 163 feet. A. T. 632. This well is at the Kleinschmidt house next to P. O.

Depth to rock 49 feet 3 inches, total depth 50 feet 6 inches. This well is 15 inches in rock at the store.

450 N., 1900 W. Depth 39 to 40 feet. A. T. 632. The water rises only 6 inches. The surface water is hard.

360 N., 50 W. Total depth 36 feet. A. T. 635. The water flowed at first, but is now 5 feet from the surface.

700 N., 50 W. Total depth 30 to 33 feet. A. T. 634. The water is about at level of ground.

1200 N., 50 W. Total depth 29 feet. Berne, 2d house from N. E. corner. A. T. 633. SO_4 and Cl low, like other wells on this road. This well used to flow and now rises to five feet from the surface.

1980 N., 880 W. Cl low, SO_4 low. Total depth 36 feet. A. T. 627. This well is at Leipprandt's store.

1950 N., 1820 W. Cl low, SO_4 medium. Total depth 31 feet. A. T. 626. This well was dug for 16 feet and drilled 16 feet.

There is no casing in this well, the stream was so strong that it lifted the one-inch casing out.

Section 3.

1320 N., 1925 W. Depth to rock 40 feet, total depth 80 feet. A. T. 626. F. D. MacCauley, owner; drilled by Hofmeister. Water was struck at 30 feet and rose to 8 or 9 feet below surface.

520 N., 1200 W. Driller, F. Mueller. A. T. 629. This well is but 9 feet deep and they found gypsum. In a dug well at 32 feet was "a big layer of gypsum," very good according to samples, but probably in the drift. On the other side of the stream he says that a well struck the same layer, say 2 feet thick, and that an adjacent drilled well cut some 4 or 5 feet of it.

20 N., 760 W. Total depth 23 feet. A. T. 629. This well was dug 22 feet and bored to rock which is not very hard. There is 14 feet of water in the well.

50 N., 1180 W. Total depth 60 feet. This is said to have been a well all in hardpan, with no casing.

1950 N., 460 W. Total depth 17 feet A. T. 612. This well was dug 14 feet and drilled 3 feet.

1950 N., 810 W. SO_4? Depth to rock 35 feet, total depth 40 feet. A. T. 626.

1950 N., 1320 W. A. T. 626. This is a shallow well.

Section 4.

1970 N., 1280 W. Total depth 18 feet. A. T. 626. This well was dry in July, 1895.

1980 N., 720 W. Depth 10 feet. A. T. 626. At house, in gravel and hardpan, quite often dry.

(2) Depth 14 feet. At barn, barely dry in hot summers. Next houses east, three wells and all were dry in summer of 1895. Total depths 14, 18 and 20 feet.

1320 N., 25 W. Total depth 35 feet. A. T. 626. This well was dug for 20 feet and hand drilled the rest of the way. Water was struck about 7 feet below surface.

750 N., 50 W. Total depth 60 feet. A. T. 626. The water in this well nearly rose to top.

700 N., 50 W. Total depth 35 feet. This well was dug 20 feet, and drilled 15 feet. It was never dry from 1892 to 1896 and was afterward drilled to 40 feet and filled up. There is gravel at the bottom.

300 N., 50 W. Depth just to rock 44 feet. A. T. 626. This well goes to rock which is limestone like the quarries.

S. E. quarter of S. W. quarter. H. Eimers' well strikes rock near surface.

1980 N., 1000 W. Total depth 53 to 54 feet. Cl low, SO_4 strong. A. T. 626. At 58 feet there is blue rock with seams of plaster.

Section 5.

1900 N., 1350 W. Depth 49 feet. A. T. 624 (42.5). This well passes through 13 feet of limestone similar to that of quarry, then 24 feet sandstone, then 4 feet soft, fine sandstone, then 7 feet (last few feet a mixture) slate and sandstone mixed.

400 N., 1950 W. Depth to rock 16 feet, total depth about 22 feet. A. T. 622.

840 N., 1950 W. This well is about 7 to 11 feet deep. A. T. about 622.

1050 N., 800 E. A. T. 630 (48.2). Surface of quarry is 51 to 52 feet above lake. This is a test bore hole at the quarry. In atlas of Huron county is a view of Bay Port quarry 40 feet down. See Fig. 8.

	Thickness.
Limestone	16
Grindstone or coarse sandstone	20
Fine sandstone, red brown or brindle	13-15
Shale, which I assign to the Michigan series	50

From 25⅓ to 29 feet the sandstone dipped decidedly according to diagram, 6:11, being cross bedded, the rest being practically horizontal stratification.

Sample marked "(1) 41 feet" is fine grained sandstone with some mica, light brown; "50 feet slate" is a shale; "Sample taken in 1884 at 9 feet, 8 in., from the bottom of this hole No. 1" is a fine grained light grey shale with laminae across core, at one end a lump of $Fe\ S_2$ weathered to sulphates. Also at the bottom of hole 100 feet from surface, a very soft grey slightly calcareous shale with a streak 1-10 inch of sand cemented with pyrite. At total depth 28 feet 3 inches the core saved was 18 feet 4 inches, a portion of loss from earthy deposits between layers.

(2)	Thickness.	Total.
Limestone	13	
Sandstone	24	37
Soft fine sandstone	4	41
Slate and sandstone mixed	7	48

The variation in the record of these two borings and the quarry section shows how variable the beds of the sandstone, etc., are.

720 N., 1950 W. Total depth 29 feet. A. T. 617. This well flowed for the first few years.

100 N., 1950 W. Depth to rock 28 feet, total depth 32 feet. A. T. 617. This well passes through rock, then through clay and gravel. (Cavern clay, or some of the shale beds of quarry record.)

50 N., 1720 W. Cl trace, SO_4 strong. A. T. 619. This well usually flows until about July 4th and then stands at surface.

50 N., 1300 W. Total depth 27½ feet. A. T. 620. This well used to flow.

260 N., 50 W. Depth to rock 16 feet, total depth 22 feet. A. T. 622.

840 N., 50 W. Depth to rock 7 to 11 feet, total depth 12 feet. This well passes through 5 feet of limestone and flint, sandstone below; 50 rods on it is 6 inches to rock.

Section 7.

950 N., 740 W. Total depth about 28 to 30 feet. A. T. 617. This is a drilled well.

950 N., 1280 W. Depth to rock 26 (?) feet, total depth 33 feet. A. T. 619. This well is in quicksand and did not flow, water rose about 6 feet from ground. Nine feet of this well is said to be in rock, the rest is in gravelly sand.

1050 N., 1900 W. Total depth 27 to 37 feet. A. T. 618. This well flowed 2 feet above ground. Cl and SO_4 not more than trace. Temperature 49½°.

700 N., 1950 W. Total depth 29 feet. A. T. 619. Temperature of flow 49° F. SO_4 trace.

50 N., 1320 W. Total depth 33 feet. A. T. 622. E. Harder, driller.

50 N., 640 W. Depth to rock 32 feet, total depth 36 feet. A. T. 624. A. Graves, owner. Water was struck at about 31 feet.

50 N., 300 W. A. T. 625. This is a shallow well at the school house.

N. W. of S. W. Total depth 24 or 28 feet. Adam Mueller, driller. These wells are of muck and clay loam. Clay 3½-4 feet, then hardpan gravel, etc.

50 N., 1950 W. Total depth 24 or 40 feet. Cl trace, SO_4 0. Temperature 50° F. This well has a strong flow at school house.

1850 N., 1950 W. This is about like flow opposite in Sec. 6.

1950 N., 720 W. Depth to rock 27 feet, total depth 29 feet. A. T. 612. T. Radloff, owner. In the spring water was at surface now it is more than 7 feet from the top.

840 N., 50 W. Total depth 25 feet. J. B. Harder, owner.

1460 N., 50 W. Total depth 40 feet. Less than 40 to rock.

1700 N., 50 W. Depth to rock 30 feet, total depth 100 feet. A. Grant, owner. The well was sunk this deep in order to get a flow, in vain.

Section 8.

A. T. about 624.

S. W. ¼. Depth to rock 21 to 26 feet; total depth 22 to 26 feet. The wells around here are to rock (F. G. Harder's place, 3½ miles E. and 1 mile south of Pigeon).

N. E. Depth to rock 2 to 8 feet.

1950 N., 1020 W. Depth to rock 25 feet, total depth 39 feet. Cl 0, SO_4 low. This well gets roily at times.

1950 N., 60 W. Depth to rock 38 feet 8 inches, total depth 110½ feet. There is a little water in this well at 40 odd feet, but not enough even now. It is very strongly cathartic, Cl 0, SO_4 strong. D. Grant, owner.

500 N., 1950 W. This well is 7 or 8 feet deep in quicksand.

450 N., 1120 W. Cl 0, SO_4 trace. Total depth to rock 33½ feet.

510 N., 1120 W. Total depth 15½ feet.

1460 N., 1950 W. Total depth just to rock 40 feet.

1700 N., 1750 W. Cl 0, SO_4 med. Total depth 52 feet. This well is in rock and the water is cold and good.

Section 9.

W. ½ of S. E. ¼. Two miles south of north part of Sec. 4. A. T. 630. Total depth 80 feet. W. Challis, owner. This well is in rock.

1680 N., 50 W. Total depth 180 feet. A. T. 628. C. J. Hofmeister, driller. This is a flowing well with over 1 foot head. Temperature of flow 48°. The water is salty.

1220 N., 50 W. Depth to rock about 30 feet, total depth 190 feet. A. T. 628. H. Maier, owner; C. J. Hofmeister, driller. This well is through soapstone, limestone and sandstone. The water was struck in sandstone and rises to within 7 feet of the surface. The temperature of water is 47° F.

380 to 420 N., 50 W. Depth to rock 2 feet, total depth 180 feet. Cl low, SO_4 0. A. T. 630. Only 2 feet to limestone which is close to the surface and like that of the quarries on Sec. 5, T. 16, R. 10; the rock drops 18 feet suddenly to north and to south slopes off gradually.

1950 N., 1540 W. Depth to rock 8 to 10 feet, then the rock limestone is 18 feet thick. A. T. 627.

50 N., 660 W. Cl low, SO_4 trace. Depth to rock 18 feet, total depth 76 feet. A. T. 630.

500 N., 600 W. Depth to rock 3 feet. A. T. 629.

Section 10.

1680 N., 1950 W. Total depth 198 feet. A. T. 628. This well is mostly through soapstone.

620 N., 1950 W. Depth to rock 24 feet, total depth 240 to 242 feet. A. T. 630. Henry Eimers, owner. D. Bullock, driller. This is about the same as at 1220 N., 50 W. Sec. 9-16-10, 24 feet to rock, 4 feet limestone, then white stuff.

50 N., 1740 W. Total depth 30 feet. A. T. 630. Temperature of flow 48° F. Perhaps this well does not strike rock. A. Aublam, owner.

1980 N., 1220 W. Total depth 22 feet. A. T. 629. This is good water.

1160 N., 50 W. Total depth 163 feet. A. T. 632. Owner, J. Reither. The water in this well is hard, the wells near by are shallow and not so hard.

1980 N., 1640 W. Total depth 22 feet. A. T. 628.

Section 11.

Pigeon village. See also Sec. 2-16-10. Depth to rock about 40 feet, total depth 150 feet. A. T. about 623. Maclean, owner.

1850 N., 950 W. Depth to rock 50 feet, total depth 223 feet. This well is at the Elevator. It passes largely through slate and soap rock, some sulphur rock, black and pyritic seams.

1900 N., 1100 W. Depth to rock 40 feet, total depth 109 feet. This well is at the Arlington house and the water rises to 5 feet below surface. Winter, proprietor. Bullock, driller.

About 1 rod away is a well 50 feet deep. This water is good and it is plenty. Fisher, blacksmith. There is a well 140 feet deep at the planing mill, and 149 feet deep at the cheese factory. Other wells are 45 to 50 feet to rock.

840 N., 1900 W. Depth to rock 63 feet, total depth 163 feet. Louis Schultz, owner. There is sandstone from 130 to 163 feet in this well.

120 N., 1900 W. Total depth 140 feet. A. T. 631. Henry Schultz, owner. The depth to rock in this neighborhood is generally 40 feet. This well is 48 feet to rock, then 1 foot blue rock, then mainly soaprock and calcareous shale down to 98 feet, from 98 to 102 water-bearing rock.

1900 N., 1337 W. Total depth 285 feet. A. T. 633. This well is at the steam stave mill, Liken and Bro. Bullock, driller. .This well got into red stuff and salt, Bullock says the red rock was 200 feet down. At 160 feet they found fresh water. The general section for Pigeon is therefore as follows.

0-50, surface.

50-90, blue clay, brick clay near surface.

90-120, sandstone, Napoleon or Upper Marshall.

120-126 (perhaps sandstone), Napoleon or Upper Marshall.

160-200, sandstone, fresh water, Napoleon or Upper Marshall.

200-285, red rock at first, with salt water, the Lower Marshall, the same as at 350 feet at Bay Port, and at 196-208 in Elkton. The Schultz well in the W. part of the section shows a dip of about 40 feet while toward Bay Port the dip must be about $(350 - 200), + (30-50) = 170 \div 5.2$ (miles) $= 33$ feet per mile.

1780 N., 50 W. Depth to rock 40, total depth 150 feet. A. T. 637. SO_4 med., Cl low. This well is cased.

1700 N., 50 W. Depth to rock 40 feet, total depth 40 feet.(?)

1440 N., 50 W. A. T. 637.

600 N., 50 W. Depth to rock 39 feet, total depth 65 feet. A. T. 639. At first the water rose 4 feet above ground and flowed, and at 50 feet the water was very hard. SO_4 mod., Cl trace. A second well in same locality is 27 feet deep.

50 N ? W. A. T. 637. Water was struck at about 70 feet. (?)

Section 12.

800 N., 1813 W. (1) Total depth 46 feet. A. T. 640. The water rises to 6 or 7 feet from surface. On top of the water-bearing stratum is a greasy or slippery blue clay which tends to close up the wells. (2) Depth 49-80 feet; closed up.

50 N., 740 W. SO_4 low, Cl low. Depth 150 feet. A. T. 644.

1950 N., 860 W. SO_4 low, Cl low. Depth about 90 feet. A. T. 641.

Section 13.

1080 N., 1950 W. SO_4 mod., Cl low. Depth about 160 feet. A. T. 640.

1900 N., 1900 W. Depth of casing to rock 47 feet, total depth 50 feet. A. T. 640.

1950 N., 1420 W. Total depth 15 feet. There are some 12 and 15 feet dug wells.

Section 14.

1930 N., 1980 W. Depth a little over 15 feet. A. T. 630. This well goes dry in summer.

1420 N., 1980 W. Depth 12 feet. A. T. 635. This well is not dry.

840 N., 980 W. Depth to rock about 75 feet, total depth 110 feet. A. T. 638. Temperature of flow 47° F. This well was drilled in 1895.

240 N., 1940 W. Depth 20 feet. A. T. 637. J. String, owner. This well was dry in summer, and another was drilled. Depth to rock 80 feet, total depth 200 feet in sandstone.

1080 N., 80 W. A. T. 642. Wells around here are said to be 175 to 200 feet deep when drilled, 14 to 16 feet when dry.

Section 15.

1300 N., 1775 W. Total depth 120 feet. A. T. 632. There was limestone with Lithostrotion at surface. The limestone was at least 3 feet thick. J. Zinzer, owner.

1950 N., 250 W. Depth to rock 50 feet, total depth 100. A. T. 632. This well was drilled by Reithel and Hofmeister in 1894

1420 N., 20 W. This well is only 12 feet deep. A. T. 632.

980 N., 20. Depth 32 feet, 12 feet dug and 20 feet bored. This well always has water.

50 N., 1240 W. Total depth 42 feet.

S. half of N. W. quarter. On H. Bergmann's farm rock occurs at or near surface.

Section 16.

1950 N., 1680 W. A. T. 628. This well is 32 to 36 feet deep according to different reports.

Section 17.

1950 N., 620 W. Cl 0. Total depth 24 feet. A. T. 627. Barr, owner.
1950 N., 1420 W. About 26 feet to rock. Total depth 26 feet. A. T. 627.

Section 18.

760 N., 1900 W. Depth to rock 40 feet, total depth 110. A. T. 622. Owner, Chas. Rather. Cl low, SO_4 low. The water rises just to the top.

1600 N., 1950 W. $SO_4$0. Total depth 30 feet. A. T. 620. This well flowed about 6 inches above ground. A sample has been sent to Lansing or to D. Fall, by Snell.

1900 N., 1000 W. A. T. 624. This well is like the others around here, i. e., about 30 feet deep.

1950 N., 940 W. Total depth 33 feet. A. T. 624. This well is drilled. The water rises to two feet below ground.

50 N., 1360 W. Depth to rock 46 to 48 feet, total depth 120 feet. A. T. 626.

Section 19.

50 N., 1440 W. Total depth 10 feet. A. T. 626. Blue sandy clay just opposite in the ditch. (Perhaps some of the wells entered under Sec. 24-16-9 belong in this section.

Section 20.

0 N., 260 W. Cl low, SO_4 strong. Total depth 235 feet. A. T. 634. The water tastes puckery.

50 N., 1000 W. Total depth 35 feet. A. T. 632. 25 feet of this well is dug and 10 feet bored in gravel.

1950 N., 740 W. Cl trace. SO_4 strong. The water has a slight inky taste. Total depth 65 feet. A. T. 628. Elmer, owner. There is no house near by.

Section 21.

1720 N., 20 W. Total depth 56 feet. A. T. 635.

600 N., 20 W. Total depth 20 feet. A. T. 637.

50 N., 700 W. SO_4 low. Depth to rock 28 feet, total depth 30 feet. A. T. 637. T. Titz, owner.

1950 N., 1740 W. Total depth 22 feet. A. T. 634. (1) 5 in. well. (2) Largely in bluish boulder clay.

50 N., 1950 W. Total depth 9 feet. This is a surface well.

Section 22.

In general it is said to be from 22 to 38 feet to rock.

1950 N., 840 W. Total depth 33 feet, 14 feet through clay and 19 feet through gravel. A. T. 637. Chas. Knott, owner. The water is moderately hard.

1950 N., 1240 W. Depth 28 feet. A. T. 637.

1950 N., 1740 W. Total depth, just to rock, 48 feet. A. T. 637. Water was struck on top of the limestone. Down to it was all clay. One-fourth of a mile south and one-half mile east it is said to be only 4 feet to limestone.

1360 N., 1900 W. Depth to rock 27 feet, total depth 40 feet. A. T. 637. A. Lindeberger, owner. This well was dug 20 feet and drilled 20 feet, and the water is roily in stormy weather.

1020 N., 1900 W. Total depth 27 feet. A. T. 637.

600 N., 1900 W. Total depth 27 feet. A. T. 637.

660 N., 100 W. Depth to rock 16, total depth 45 feet. A. T. 637. On the 40 acres of August Blunde, only 4 to 5 or 8 feet to rock.

Section 23.

1740 N., 1950 W. Total depth 210 to 220 feet. A. T. 640. W. Wagner, owner. The water is too bitter for cooking (i. e. SO_4 strong), Cl trace. Tastes of S and Mg.

1240 N., 1950 W. Total depth 30 feet. A. T. 641. This well is never dry.

1900 N., 50 W. SO_4 strong, Cl trace. Depth to rock 70 feet, total depth 125 feet. A. T. 645. S. Foster, owner.

1000 N., 50 W. SO_4 low. Depth to rock 150 feet, total depth 223 feet. A. T. 643. This well is cased for 150 feet. The first rock is soaprock, it is mainly blue rock and not so very hard, then 35 to 40 feet of sandrock, i. e., about 185-223. As the SO_4 is low it is probable that it begins below the gypsiferous layers of the Michigan series which lie more than 35 feet above the Napoleon sandstone.

Center of the N. W. ¼ of the S. E. ¼. Depth to rock 96 feet, total depth 145 feet. A. T. 645. F. J. Reithel, owner.

S. E. ¼ of N. W. ¼. 1050 N., 1100 W. A. T. 645. Cl trace, SO_4 strong, cathartic, alum taste. This water "hardens butter." Depth to rock 90 to 99 feet. Total 99 feet. This well is through soft rock. B. Franklin, owner.

500 N., 1950 W. Cl trace, SO_4 strong. Total depth 137 feet. A. T. 644.

Section 24.

1950 N., 1250 W. Depth, not to rock 70 to 80 feet. A. T. 645.

Section 25.

50 N., 340 W. Depth to rock 14 feet. A. T. 648.

1950 N., 1950 W. Total depth 100 feet. A. T. 648. This is a new well, Aug. 28, 1896, and has 100 feet 3 inches casing, but is not to rock yet. There is plenty of water in this well.

Section 26.

1925 S., 75 W. Depth to rock 75 feet, total depth 141 feet. A. T. 647. J. Decher, owner. Fred J. Reithel, driller. This well passed through soaprock, then limerock and hard slate, blue argillaceous limestone and dolomite (cement rock). This well was deepened to 144 feet on Aug. 28th. Cl trace, SO_4 strong.

Section 27.

1820 N., 1950 W. Total depth, not to rock, 38 feet. A. T. 637. This well was dug 12 feet and then drilled to gravel. There is another well on the other side of the road. Depth to rock 31 feet, total depth 61 feet. A. Hartman, owner.

1000 N., 1900 W. Total depth 60 feet.(?) A. T. 637.

100 N., 1260 W. Depth to rock 68 feet, total depth 100. A. T. 630. Soaprock, sandstone at 100 feet. John Lucht, owner.

100 N., 840 W. A. T. 641. This well was down 138 feet to rock on the forenoon of June 3d, 1896, through clay, sand and gravel. Engelhardt Stueck, owner. Chas Hofmeister, driller.

Cf. Brown's well on § 23 in Fairhaven, T. 16 N., R. 10 E.

680 N., 1950 W. 148 feet to rock, 160 feet deep. A. T. 637. Louis Kain, owner. This well used to flow.

Section 28.

50 N., 950 W. A. T. 636. SO_4 strong.

840 N., 50 W. Cl low, SO_4 strong. Total depth 220 feet. A. T. 636. This well passed through much soaprock.

480 N., 30 W. SO_4 strong. School district No. 1. Winsor. Sept. 30, 1895. A. T. 636. Record of J. Russell as follows:

	Thickness.	Depth.	
Red clay	12	12	Post-glacial.
Blue clay	39	51	
Hardpan and boulders	3	54	Glacial.
Sand and gravel	1	55	
Hardpan and boulders	19	74	
Light slate rock	7	81	Michigan series.
Black slate rock	2	83	
Light slate rock	3'6"	86'6"	

Cf. Brown's well on § 23 in Fairhaven, T. 16 N., R. 10 E.

1950 N., 1950 W. Total depth 41 feet. A. T. 634. This well goes through soapstone (probably solid clay).

50 N., 1900 W. Cl low, SO_4 strong. Depth about 60 feet. A. T. 636.

50 N., 660 W. SO_4 low. Total depth 85 feet. A. T. 636. This well passed through a few feet of gravel, then it was hand drilled for 27 feet through hardpan, i. e., till; then sand 9 feet thick was found at 45 feet, then 18 feet of soapstone, 2¾ feet of hard rock.

1950 N., 1240 W. SO_4 med. Depth 45 feet or more. A. T. 635.

Section 29.

50 N., 700 W. SO_4 strong. Depth to rock 69 feet. A. T. 636. Wm. Weinlander, owner. Chas. Hofmeister, driller. Record of samples sent to survey:

126 to 128, sandstone fine grained arenaceous.

128 to 150, yellow and brown limestone and sandstone.

150 to 216, clear white sand (a few green grains of spinel?) apparently good enough for glass making.

50 N., 1820 W. Total depth about 183 feet. A. T. 632. The water is very hard, Cl trace, SO_4 strong. W. Kappen, owner.

50 N., 1100 W. Total depth 125 feet, about 59 feet casing. A. T. 636.

50 N., 940 W. Cl trace, SO_4 strong. Depth to rock about 69 feet, total depth 148 feet. A. T. 636. Miller, owner. C. Hofmeister, driller. At 82 feet dolomitic limestone; 107-148 sandstone slightly calcareous.

50 N., 260 W. Total depth 188 feet or more. A. T. 637.

1660 N., 50 W. Depth to rock about 70 feet. A. T. 635.

1950 N., 1000 W. A. T. 632. Cl trace, SO_4 strong. This water is cathartic and probably comes from decomposed pyrite. Depth to water 60 feet, total depth 225 feet. Jacob Holst, owner. This well is through soaprock and at 160 feet ("stuff like gold, called sulphur") pyrite.

Section 30.

(Depth to rock said to be in general about 60 feet.)

140 N., 1950 W. Total depth 200 feet or more. A. T. 630. This well is mainly shale and soaprock. C. Buschlein, owner.

50 N., 700 W. Cl 0, SO_4 med. + total depth 40 feet, but not to rock. A. T. 632.

Cl trace, SO_4 strong. Depth to rock 60 feet, total depth 180 feet. A. T. 632. M. Regenscheit, owner; C. Hofmeister and Crafts, drillers.

1000 N., 50 W. Cl trace, SO_4 strong. Depth to rock 64 feet, total depth 220 feet. A. T. 631. From 200-215 in sandstone. The tools were stuck fast, and some pyrite was encountered. George Kramer, owner; Smith, driller.

Section 31. (Kilmanagh.)

50 N., 540 W. Total depth about 60 feet. A. T. 630. This is like the well just south.

50 N., 990 W. A. T. 630.

50 N., 1300 W. Cl low. About 100 feet deep. This well is cased to rock for 80 feet. There was hard rock at the top of bed rock. C. Heckert, owner.

A. T. 630. Geo. Kindig, owner. Record as follows:

	Thickness.	Total.
Clay	55	
Hardpan with boulders	3	58
Loose dark rock (hard slate)	4	62
Hard rock, water	5	67
Soapstone	6	73
Light colored hard rock with 8-16 in. soft seams	25	88
Sandy fine clay, slate	4	102
White hard sand rock with some pyrite	4	106
Soft white sand rock	21	127

SO_4 trace.

1460 N., 1950 W. Total depth about 185 feet. A. T. 630.

1950 N., 700 W. Cl trace, SO_4 med. Depth to rock about 64 feet, total depth 200 feet. A. T. 630. This is mainly through soaprock, water was struck in sandrock.

1200 N., 50 W. Cl low, SO_4 med. Total depth about 170 feet. A. T. 636. Gottleib Layhen, owner.

50 N., 50 W. Depth to rock 60 feet, total depth 85 feet. A. T. 638.

A. T. 630. Frank Thompson, owner. Cl low, SO_4 med.

	Thickness.	Total.
Clay	60	
Slate or soap	10	70
Hard rock	25	95
Hard sandrock	12	107
Water sandrock	12	119

Section 32.

50 N., 660 W. This well was drilled. A. T. 676.

50 N., 1760 W. SO_4 low, Cl low. Depth to rock 80 feet, total depth 155 feet. A. T. 637. C. Finkbeiner, owner. The first rock encountered was slate, the last 25 feet was sandrock in which was water. Water also occurred at the surface of the rock

1950 N., 1820 W. Depth to rock 64 feet, total depth 172 feet. A. T. 636.

1950 N., 1100 W. Cl low, SO_4 med. Depth to rock 59 feet, total depth 116 feet. A. T. about 636. S. Ellenbaum, owner. The water has fallen from five feet below ground to 14 feet below.

1960 N., 940 W. Depth to rock 35 feet,(?) total depth 178 feet. A. T. about 636.

1950 N., about 300 W. Cl strong, SO_4 strong. Total depth 186 feet or more. J. D. Finkbeiner, owner.

Section 33.

1360 N., 20 W. Total depth 14 feet. A. T. 637. This well is shallow in gravel and gravelly clay.

750 N., 50 W. Total depth 135 feet. A. T. 637. Wm. Hinton, owner.

50 N., 1700 W. SO_4 trace, Cl med. Depth to rock 90 feet, total depth 170 feet. A. T. 637. Jacob Kain, owner.

1950 N., 1800 W. Cl tr., SO_4 strong. Total depth 226 feet. A. T. 635. This water is cathartic.

1950 N., 1300 W. A. T. 635. Cl trace, SO_4 strong. Total depth about 214 feet. This well has 70 or 80 feet of casing.

Section 34.

1900 N., 1260 W. Depth to rock 104 feet (or 96), total depth 175 feet. Henry Einwochter, owner.

820 N., 1950 W. A. T. 637. Depth to rock 120 feet, total depth 165 feet. Cf. § 3-15-9.

Section 35. (Linkville, = Winsor, = Kilkenney). A. T. 648.

100 N., 950 W. Depth to rock 73 feet, total depth 101 feet.

	Feet.
Blue clay	71
Red clay	71-73
Grey rock	73-101

100 N., 950 W. Strong of SO_4. Depth to rock 75 feet, total depth 105. This well is in soapstone and hard black rock. C. Link, owner.

150 N. Total depth 225 feet. This well is at the stave mill, and has about 40 feet of red rock at the bottom.

50 N., 950 W. SO_4 trace, Cl low. This well is at the saw mill and has 120 feet casing. There was a bad flow from 105 to 110 feet, but it is cased off. "Grindstone" occurs from 135-140 feet and 150 to 200 feet.

1050 W. Total depth 173 feet. SO_4 low, Cl low. The water rises to about 10-12 feet from the ground.

Probably 1 and 2 are the same well, but different reports, also 3 and 4. The general section would then be probably (compare Grand Rapids Pl. XXI, Vol. V, Geol. Sur. Mich., at 147, 191 to 248, and 248 to 265 feet).

	Feet.
Drift	70-75
Grey calcareous shale	75-101
Hard black rock, perhaps limestone, and gypsum, brackish water	101-120
Shale	120-140
Sandstone	140-185
Red sandstones and shales	185-225

880 N., 50 W. Total depth 16 feet. A. T. 645.

50 N., 1950 W. Dug in boulder clay.

Oliver Township (T. 16 N., R. 11 E.).

50 N., 1520 W. Total depth 10 feet. A. T. 667.

Section 2.

50 N., 700 W. SO_4 strong, Cl low. Temperature of flow 51° F. Total depth about 150 feet. A. T. 657.

50 N., 1100 W. Depth to rock 26 feet, total depth 142 feet. A. T. 663. This is a flowing well in very hard rock.

Section 3.

1900 N., 300 W. Depth to rock 25 feet, total 146. A. T. 644. Salt at 48 feet. This well used to flow 2 feet above ground, the water is salty and at 143 feet was not good. This well should be cased deeply. Compare Adams' well in Caseville; i. e., about 90-100 feet above the sandstone is a salt streak.

1780 N., 1900 W. Depth to rock 26 feet, total depth 239 feet. A. T. 647. At 180 feet the water was not good. It now rises to within 6 feet of the ground.

220 N., 1540 W. Cl trace, SO_4 low. Total depth 130 feet. This well is cased for 30 feet. A. T. 645. This well is at the brick yard.

Section 4.

1950 N., 1480 W. Total depth dug, and not to the rock, about 12 feet. A. T. 657.

Section 5.

50 N., 960 W. Total depth about 20 feet. A. T. 657.

700 N., 1950 W. SO_4 low, Cl low. Total depth 109 feet. A. T. 647. D. Bullock, driller, for Dwight and Heywood.

1420 N., 1950 W. SO_4 low, Cl low. Depth to rock 95 feet, total depth 156 feet. A. T. 647. D. Bullock, driller. The question is, is this casing really only to rock or did they case deeper to keep off bad water? The rock was blue "like slate pencils," i. e., blue shale in the Michigan series.

1950 N., 1280 W. SO_4 med. Cl low, like the one in Sec. 32-17-11. Depth to rock 60 feet, total depth 150 feet or more. A. T. 647. This well is in blue shale and sandrock.

1950 N., 1210 W. SO_4 med., Cl low. Depth to rock 40 feet, total depth 168 feet. A. T. 647. Fliege, owner.

Section 6.

360 N., 50 W. SO_4 trace, Cl low. This well is 50 to 60 feet to rock and 125 feet deep. A. T. 647. This well was put down by D. Bullock for J. E. Lynch.

160 N., 1950 W. Total depth 29 feet. A. T. 646. This well was dug for 11 feet, then hand drilled. The water rose to within 12 feet of the surface.

800 N., 1950 W. Total depth 40 feet. A. T. 642. This well was dug and drilled, and has not very much water. SO_4 low, Cl med.

1950 N., 1460 W. Total depth 40 feet, hand drilled. A. T. 640. Good supply of water.

1950 N., 980 W. Total depth 140 feet or more. A. T. 642. This well is a few feet deeper than next well east, which is steam drilled.

W. half of N. E. quarter. Total depth 140 feet, depth of casing 52 feet. A. T. 642. J. Ackerman, owner.

Section 7.

60 N., 1950 W. SO_4 trace, Cl trace. Depth to rock 48 feet, cased for 2 feet or more, total depth 68 feet. A. T. 646. D. Bullock, driller; A. Neely, owner.

Section 8.

The surface wells around here vary from 50 to 65 feet deep.

560 N., 50 W. A. T. 652. Not to rock.

600 N., 50 W. Depth to rock 50 feet, total depth 82 feet. A. T. 652.

1450 N., 50 W. SO_4 trace, Cl low. Depth to rock 58 feet, total depth 166 feet. A. T. 652. Hoffman, owner.

100 N., 1950 W. Total depth 14 feet. A. T. 648. This well is in hard, tough, drab, very compact hardpan or boulder clay. This well was not finished.

1600 N., 1950 W. A. T. 650. This well was not drilled.

Section 9. (Elkton)

135 N., 37 W. Total depth 215 feet. John Grill, owner. SO_4 trace, Cl low.

There were flows of water at 66 feet, but at 110 feet came the regular flow. The rock consists of slate rock, black rock "coal" (not so), white rock, and passing through the sandstone the well goes into 10 feet of red rock. This well is cased to rock and piped to 110 feet. When the wind came from the S. E. it flowed a 1-inch stream, when from N. or W. it did not flow. This well used to flow until they cut the packing of the R. R. well 4 feet below ground.

125 N., 37 W. Cl. med. Total depth 23 feet. Compare sec. 10.

1900 W., 600 N. SO_4 trace, Cl low. Depth to rock 55 feet, total depth 80 feet. This well starts in sandy soil. H. Becker, owner; 50 to 65 feet is the usual depth of surface wells around here.

Section 10. (Elkton)

There are two or three wells for engines 2½ miles east of Pigeon.

Andrew Newly, 18 to 28 feet of white rock (gypsum)?

"There are 14 or 15 wells right in Elkton and they are robbing each other and wells that used to flow do so no more."

150 N., 1800 W. Depth to rock 25 feet, total depth 228 feet. A. T. 650. S. T. and H. R. R. station. Cf. John Grill's well on Sec. 9. Summary:

	Feet.
Surface	0-25
Mainly sand rock with occasional seams of slate and limestone	25-99
Sand rock (hard down to 170 feet)	99-196
In soft red rock, slate	196-208

Water would flow at 207 feet, five feet or over above ground. Drilled by Cyrus G. Wells, of Badaxe, under a contract dated October 10, 1890. Daily report:

Oct. 23, 1890. Reached 25 feet below surface and struck rock.

Oct. 24, 1890. From 25 to 35 feet sand rock; occasionally an inch or two of slate.

Oct. 25, 1890. From 33 to 40 feet, hard sand rock.

Oct. 27, 1890. From 40 to 58 feet, hard sand rock, intermediate layer of about 6 inches of limestone.

Oct. 28, 1890. From 58 to 75 feet, hard sand rock.

Oct. 31, 1890. From 75 to 99 feet, hard rock and slate.

Nov. 4, 1890. From 99 to 102 feet, very hard sand rock.

Nov. 6, 1890. From 102 to 120 feet, hard sandrock.

Nov. 7, 1890. From 120 to 129 feet hard sand rock.

Nov. 8, 1890. From 129 to 130 feet, hard sand rock.

Nov. 10, 1890. No progress, hard sand rock.

Nov. 13, 1890. From 130 to 140 feet, hard sand rock.

Nov. 14, 1890. From 140 to 145 feet, hard sand rock.

Nov. —, 1890. From 145 to 150, hard sand rock.

Nov. 20, 1890. From 150 to 158 feet, hard sand rock.

Nov. 22, 1890. From 158 to 170 feet, hard sand rock.

Nov. 25, 1890. From 170 to 178, soft sand rock.

Nov. 26, 1890. From 180 to 196, soft sand rock.

Nov. 28, 1890. From 196 to 202, soft red rock.

Dec 2, 1890. Down 207 feet, red soft rock; broke down, not drilling at present.

Dec 6, 1890. Well will flow, if fixed with piping and packing, five feet or over, above ground.

Dec. 6, 1890. Down 208 feet in red slate; the pipe has been put in and tried and water flowed five feet above surface.

1200 N., 950 W. Total depth 130 feet. A. T. 642. SO_4 med., Cl low. This well does not flow.

Section 11.

1950 N. Total depth 170 feet.

1950 N., 50 W. Depth to rock 26 feet, total depth 130 (128 to 138) feet. A. T. 664. Water at first rose to 3 feet from surface, and was struck at 100 feet.

1000 N., 50 W. SO_4 med., Cl trace, taste of $H_2 S$. Depth to rock 100, total depth about 130 to 170. Wells of D. Rolph and neighbors. This well did flow.

Section 12.

1950 N., 540 W. Depth to rock 25 feet, total depth 220 feet. A. T. 670. This well is mainly through slate and soapstone. The first water was at 90 feet. This well flowed for sometime and the water is now within 4 feet of the ground.

Section 13. Grassmere.

1040 N., 50 W. Cl 0, SO_4 0. Depth to rock 40 feet, total depth 175 feet. A. T. 694. This water was tested by Prof. W. B. Prescott as follows: Hardness, 0.171 per thousand. Cl = 0.0025 per thousand; contains Ca, Mg, Na, Cl, SO_4, Cl and Co_2 in minute quantities and trace of Fe. This well goes 48 feet, to a bluish grey sandstone, shelly, i. e., flags. At 158 feet is a coarse grey sandrock.

Concerning the behavior of this well we insert the following from the Bad Axe Republican of Aug. 10, 1900. Compare what we have said on p. 126 about varying flows. The sweating of the pipe in times of storm is due to the extra humidity of the air which is congealed by the cold pipe.

> Practically all of the water used for drinking purposes at the little hamlet of Grassmere comes from a well on the Grassmere stock farm. The well stands just inside a field on the road near the station and is patronized by everyone in the vicinity as the water is very pure, clear and cold. An iron pipe has been driven into the earth to a depth of 170 feet and the water from it is carried to a large trough in the adjoining barnyard where the cattle on the farm are watered. Where the pipe comes out of the ground a barrel has been sunk in the earth and the water flows direct from the well into this barrel. Manager Sam Goodwill says this well has several peculiarities that are odd, to say the least. When the wind is in the southwest the flow of water is abundant, but let it veer around to the opposite point of the compass and the supply is diminished at least one-half. The well is also a faithful barometer. When a storm is in the air the water in the barrel is greatly disturbed. It boils violently and the sediment at the bottom rises and roils the water so that it has to be taken direct from the pipe for drinking purposes. At the same time the pipe, otherwise dry, becomes covered with moisture and great beads of perspiration drop from its rough, iron surface. This is due doubtless to the coldness of the pipe condensing the moisture already gathering in the warm air surrounding it. On Saturday all the conditions were present, and that night this vicinity was visited by a copious and welcome rain storm.

Section 15.

860 N., 1950 W. A. T. 650. This is a flowing well and is about the same as 800 N., 50 W., 16-16-11.

Section 16.

200 N., 50 W. A. T. 650. This is a shallow well.

800 N., 50 W. This is a flowing well. Depth to rock 35 to 40 feet (25), total depth 140 feet.

1950 N., 980 to 1620 W. SO_4 low. Total depth 12 to 16 feet. A. T. 647. There is no rock well near here.

Section 18.

1950 N., 220 W. Depth to rock 82 feet, total depth 304 feet. A. T. 650. Meredith, owner. At 180 or 190 there was plenty of water but they went lower hoping for a flow and got bad water, which was shut off. From 200 to 304 is red rock.

Section 21.

S. E. quarter of S. E. quarter. Depth to rock about 30 feet, total depth 85 feet. A. T. 670. Temperature of flow 47½° F.; water not as hard as that of the 16 foot well at the same place.

800 N., 50 W. Flow not strong. Total depth 91 feet.

1260 N., 50 W. Depth to rock 27 feet, total depth 104 feet. A. T. 662.

1740 N., 50 W. Temperature of flow 47½° F. Total depth 104 feet. A. T. 660.

Section 22.

800 N., 50 W. Total depth 20-30. A. T. 665.

Section 27.

½ mile E. and ½ mile N. of 1280 N., 50 W. in Section 28. Total depth 110 ft. A. T. 672.

1920 N., 1950 W. Depth to rock 30 to 35 feet, total depth 110 feet. A. T. 672. This well is like the one 1280 N., 50 W., in Sec. 28-16-11.

0 N., 440 W. Ca trace, Cl none, SO_4 none. Total depth 149 (140 to 145) feet. A. T. 684. John Wooster, owner. This is a flowing well.

Section 28.

50 N., 320 W. A. T. 670. Paul Praseham, owner. This is not a flowing well.

50 N., 780 W. A. T. 670. This well is probably to rock, 32 feet deep.

1280 N., 50 W. T. 47½° F. Depth to rock 30 to 35 feet, total depth 106 feet. A. T. 670. This well is through sandrock and some slate, and did not have a strong flow.

750 N., 50 W. Total depth 140 to 145 feet. A. T. about 670. This is a flowing well.

1920 N., 50 W. Depth to rock about 30 to 35 feet, total depth 110 feet. A. T. about 670. This well is like 1280 N., 50 W.

Section 29.

50 N., 800 W. A. T. 667. This is a fifteen-foot dug well.

50 N., 400 W. A. T. 667. Total depth 16 feet. This is a dug well. The country is sandy all along here and to the west.

Section 30.

112 N., 1560 W. Depth to rock 54 feet, total depth 178 feet. A. T. 652. Head of flow 6 feet. J. Cassinke, owner. The first rock was sandstone at 54 feet, lots of slate in the rock, blue sandstone, then 7 or 8 feet of clear white sandstone, water bearing rock. According to Bullock, of same well, soaprock, lime and slate made up the well which went from 130-178 into sandrock.

Section 31.

1950 N., 460 W. Total depth 13 feet. A. T. 660. 4 feet of gravelly sand, the rest is clay. There was about 6 feet of water in this well all summer.

Section 33.

1950 N., 780 W. Depth to rock 30 feet, total depth 127 feet. A. T. 662. SO_4 trace, Ca trace, Cl 0. Fe present. Fred Elbe, owner. At 35 feet went through gypsum bed 1 foot thick. Water was struck at 127 feet, it flowed a water pail a minute and rusts iron. Temperature 47½° F., Lane, 48° F., Davis.

Section 36.

S. E. corner. Ca low, Cl trace, H_2SO_4 low. Total depth 13 feet. A. T. 730. This water is strongly impregnated with H_2S. When wind is E. water is said to turn black.

Colfax Township (T. 16 N., R. 12 E. L.).

Section 1.

50 N., 1900 W. Total depth 20 feet. A. T. 734. This well is not deep enough.

Section 6.

200 N., 260 W. Depth to rock 30 or 35 feet, total depth 242 feet. A. T. 690. The water was good and rose to surface. B. Kreutziger, owner. There was loose rock to 35 feet to which it was cased. At 85 feet the water rose to the top. The well was continued through soap rock in the vain endeavor to get more head, though the supply was increased.

N. W. quarter of N. W. quarter. Total depth to rock 40 feet.

100 N., 1260 W. A. T. 670. J. Klemmer, owner. Cl 0, SO_4 med. The water rose originally to 3 feet of surface, now it rises to 7 feet of surface. Water was struck at 50 or 70 feet, then 21 feet hard rock, then 4 feet of plaster.

A general section for this part of the country is 20 feet to rock, 21 feet to flinty limestone, gypsum and calcareous shales to top of Marshall sandstone at 70 feet, and at 240 feet were shales of the Lower Marshall.

Section 7.

N. W. quarter of N. W. quarter. Depth to rock 20 feet, total depth 150 feet. A. T. 677. This well flowed at first.

Section 9.

A. T. 708. Total depth 26 feet. J. Hutchinson, owner. The water in this well is not good.

Section 13.

1300 N., 50 W. Total depth 15 to 16 feet. A. T. 752.

1950 N., 860 W. Total depth 12 to 16 feet. A. T. 744. This is the general depth of wells around here.

Section 18.

200 N., 50 W. Cl 0, SO_4 0. Depth of casing to rock 40 feet, total depth 85 feet. A. T. 709. The water rises to 3 feet from top.

A. T. 693. Grassmere. See Sec. 13, Oliver. Around Grassmere wells are said to be about 90 feet deep.

Section 20.

340 N., 50 W. Depth to rock 60 or 70 feet, total depth about 200 feet. A. T. 745. Fred Wettzel, owner. This is a sandstone water. D.

S. W. ¼ of S. E. ¼. Depth to rock 50 feet, total depth 75 feet. A. T. 745. Robt. I. Hazard, owner. This well used to flow.

Section 23.

1000 N., 640 W. Total depth 8 to 9 feet. A. T. 762.

1050 N., 1060 W. Total depth 10 to 12 feet. A. T. 762.

1250 N., 1200 W. Depth to rock 50 feet, total depth 85 feet to 102 feet. A. T. 762. This well is at the county poor house, in soaprock (?).

1200 N., 1250 W. Total depth 91 feet. A. T. 762. This well is at the road.

220 N., 1950 W. A. T. 757. The water rose 8 feet from top.

Section 24. (Badaxe.)

T. Rapson says that it is mostly sandstone around here, now and then soapstone, but as we go north toward Grindstone City there is very little rock (i. e. sandstone) until the soapstone, then 100 to 200 feet of soapstone with seams of sandsone, i. e., Lower Marshall. Other deep wells generally to rock are put down in Badaxe at the jail, Connaton House, Bank of F. W. Hubbard & Co., Post and Seely, Skinner, School house and R. R. station, etc.

Lot 17, John Street, 1400 N., 700 W. Depth to rock 40 feet, total depth 90 feet. A. T. 770. S. Burgess, owner.

1050 N., 1050 W. Total depth 80 feet, in rock. A. L. Wright, owner.

1450 N., 1800 W. Depth 10 to 12 feet. This well is at the cemetery and went through 4 feet gravel, 4 to 12 feet sand, and the rest clay.

A. T. 770. Depth to rock 56 feet, total depth 110 feet. Well at the new cemetery, drilled in 1896. This well was through sandstone, with no change all the way. This compared with the flowing well on Sec. 10-16-13, Verona, shows that there is a very heavy sandstone at the top of that.

Section 26.

1780 N., 1950 W. A ten-foot well in hard clay, not stoned up. A. T. 752.

Section 27.

1780 N., 50 W. Seven feet hard blue clay, 6 inches gravel, 4 feet blue clay, then more gravel. A. T. 752.

Section 29.

1950 N., 260 W. Depth to rock 60 feet, total depth 66 or 75 feet. A. T. 745. The first 60 feet were mostly clay, but there were 12-15 feet of quicksand on the rock, and 5 to 6 feet sandrock at the bottom. The water rose to within 4 feet of the surface, it was clayey but otherwise good.

50 N., 300 W. Total depth, not to rock, 18 feet. A. T. 762.

Section 30.

440 N., 200 W. Depth to rock 60 feet, total depth 66 feet, or depth to rock 70 feet, total depth 75½ feet. A. T. 730. Robert Brown, owner; T. Rapson, driller.

	Thickness.	Total.
Clay	45	45
Quicksand on top of rock	12 to 15	60
Sandrock	5 to 6	66

The water rose to within 15 feet of the surface. There was good water in this well which rose to 16 feet of surface.

Section 32.

1950 N., 140 W. Total depth 12 feet. A. T. 765.

Section 33.

E. half of S. E. quarter. Total depth 17 feet. A. T. 757.

Section 34.

1950 N., 260 W. Total depth 12 feet. A. T. 770. This well is in clay but the road is sandy.

920 N., 50 W. In Sec. 35 (?). Depth 18 feet. A. T. 762. Ten feet to water through a bluish gravelly clay with much white chert.

480 N., 50 W. Depth 13 feet. A. T. 764. This well is through the clay which seems to "drop out" at the bottom, with a quicksand and gravel beneath yielding plenty of water.

50 N., 1565 W. Total depth 20 feet or more. A. T. 764. This well struck water at 20 feet.

50 N., 1950 W. Total depth 18 feet. A. T. 760. This well is through gravel into coarse gravel. The water is very hard and "furrs the kettle right up."

Section 35.

1450 N., 950 W. Total depth 6 feet. A. T. 752.

1050 N., 1950 W. A. T. 760.

Verona Township (T. 16 N., R. 13 E. L.).

Section 6.

1037 N., 1476 W. Probable depth 63 feet. A. T. 750. There was plenty of water in this well for 30 head of cattle, and it rose nearly to the top.

Section 7.

50 N., 1950 W. Total depth 10 to 12 feet. A. T. 770.

1180 N., 1950 W. Total depth 10 to 12 feet. A. T. 750.

Section 11.

1000 N., 1000 W. Depth to rock 50 feet, total depth 60 feet. A. T. 756.

Section 18.

1950 N., ? W. Total depth, just to rock, 40 feet. A. T. 770. Mott, owner.

1000 N., 1950 W. Depth to rock 40 feet, total depth about 85 feet. A. T. 712. H. Wilcox, owner.

Section 19.

830 N., 1700 W. June 2d, 1896. See record from J. Coreyell, see also analysis of Badaxe water below. These wells rose to 11 feet below ground, now they have to raise it about 15 feet.

About 300 feet south and 800 feet E. of W. ¼ post of Sec. 24, on Hanselman street. Depth to rock 40 to 45 feet, total depth 200 feet. A. T. 760. Waterworks of Badaxe. Very pure from mineral matter. T. 49° F.

The town is supplied by these three artesian wells, about two hundred feet deep, from which the water is pumped to the stand pipe, 200 feet high. The record turned in by Coreyell below may be from one of these wells by mistake as it does not match that of the 400 foot well which it was supposed to be. I copied the original record of the latter. The main flow is at about 200 feet. During the summer there was some complaint of the taste of the water, and I was shown a piece of wood which was said to have come up from the well. But in spite of my tests showing that the trouble was not with the water as it came from the well, it seemed wise to send off to the Agricultural College and have the water tested. Two samples were sent. No. 1 was from the dead end of a water main, i. e., beyond any water connection to a house. No. 2 was from a pump direct. The following was Prof. F. S. Kedzie's report:

"The two samples of water sent some time ago have been very carefully examined with the following result:

	(In grains per imperial gallon.)		
	No. 1.	No. 2.	Lansing city.
Total solid matter in a gallon	23.45	20.65	19.00
Organic	7.00	6.30	4.00
Inorganic	16.45	14.30	15.00
Hardness, degrees of	5.9	5.2	13.00
Free ammonia	0.0024	Slightest trace.	0.08
Albuminoid, degrees of	0.072	0.048	0.10

(Lansing City water given for comparison.) We consider this water very good, and I think that your water may be safely placed in the same class if not better. We are, however, always troubled with bad water at the dead ends of the mains, and find it necessary to have the pipes frequently flushed. The cause for the bad smell and taste given to the water by standing at the dead ends of the pipes is thought to be the organic matter acting on the sulphate of lime contained in the water, causing the liberation of H_2S in the water which gives the water a strong and decidedly unpleasant smell when the faucet is first opened in the morning. We are never free from that trouble here, and probably never will be, so long as the water contains the lime compound and the amount of organic matter which seems to be natural to most of our Michigan waters. The only remedy is frequent flushing."

The Badaxe water does not contain anything like as much $CaSO_4$ as the Lansing certainly, and from my inspection I am inclined to attribute the difficulty more to the rapid growth of vegetable matter in the stagnant ends or stand pipe in a water with much carbonic acid. But the well water is extremely pure. It will be well to exclude light from the stand pipe.

Sand Beach Ave., White Elm. At the Morrow House there is a shallow well.

Heisterman and Sand Beach Ave. Post and Seeley's bank.

Sand Beach Ave. and Hanselman's deep well at Hubbard's bank.

Block 11, Irwin and Hanselman Street. Skinner, owner.

Block 8. There is a deep well at the school house.

A. T. 758. Total depth 40 feet. This well is at the R. R. Station. This well is through solid clay. "Clay is not as thick on hills as in lowlands."

E. part of town. Locke's well is just 49 feet to rock.

970 N., 12 W. Total depth 400 feet. A. T. 757. John Sullivan, driller. This well flows a strong stream 3 feet above ground at the rate of 1 quart per second. Temperature 47° F. Lane or 49° F. Davis. The two thermometers were about 2° apart. SO_4 0, Cl 0, Ca slight traces.

Fifteen feet was unaccounted for in depth to rock, probably 5 feet of muck; also 5 feet unaccounted for in the total. Size of hole 5⅝ inches. This I copied from original record which was hunted up for me. Depth to rock 45 feet.

	Thickness.	Total.	
Muck and shell marls? not in record	5	......	Pleistocene.
Clay	20	......	
Gravel	5	......	
(Glacial) hardpan	5	*45 or 50	
Sand rock	30	80	Upper Marshall, Napoleon.
White shale	5	85	
Sand rock	30	115	
Lime rock	8	123	
Sand rock	30	153	
Lime rock	10	163	
White shale	27	190	

Here is said to have been the main flow at about 200 feet or 175-200 feet (i. e., by record 190-215), according to report through W. L. Webber from J. Coreyell at 270 feet was sandstone with a strong stream of water rising above surface (probably read 207 for 270 feet).

	Thickness.	Total.	
Sand rock	25	215	Port Austin sandstone?
Lime rock	5	220	
White shale	10	230	
Sand and lime	20	250	Point aux Barques sandstone?
Blue shale	25	275	
White shale	20	295	
Red sand	5	300	Grindstone quarry beds?
Black lime	7	307	
Sand rock	5	312	
Black lime	5	317	
Gravel and sand rock (conglomerate)	3	320	*Bottom of Lower Marshall.*
Blue shale	15	335	
Lime rock	5	340	Coldwater shales.
Sandy shale	10	350	
Lime rock	10	360	
White shale	40	400	

John Coreyell's record through W. L. Webber, dated May 11, 1894. This is evidently not a record of the same well as above, although it was supposed to be; it may be one of the city waterworks wells.

	Thickness.	Total.
Gravel	12	12
Hardpan	20	32
Blue clay	7	39
Gravel	3	42
Hardpan	2	44
Sandrock	20	64
Blue shale	36	100
Sandy shale, blue	21	121
Sticky shale	22	143
Sandy shale	2	145
Grey sandrock	45	190
Blue shale	7	197

Cf. letter of W. L. Webber, Nov. 3d, 1896.

1037 N., 1963 W. Total depth 18 feet. A. T. 770. At the Irwin House. This well never goes dry.

Hanselman street. A. T. 760. This is a shallow well at the county jail.

Section 20.

950 N., 460 W. A. T. 768. This well is on a gravelly rise.

1050 N., 50 W. Total depth 16 feet. A. T. 782. This well went dry in the summer of 1895.

Section 21.

1050 N., 1120 W. Total depth 16 feet. A. T. 765. This well is on a muck, sand and gravel knoll. All the wells around here are shallow.

950 N., 500 W. A. T. 772. This well contains 5 to 6 feet of water.

Section 22.

950 N., 1280 W. Thomas Rapson, driller.

1050 N., 700 W. Total depth 20 to 22 feet. A. T. 807. This was a dug well.

Section 25.

1760 N., 0 W. Depth to rock 78 feet, total depth 84. A. T. 812. Sandstone water.

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*Totals obtained by subtraction from 400 feet leaving discrepancy indicated by 45 = 50.

Section 29.

1650 N., 140 W. Total depth 16 feet. A. T. 782. D. McCrea, owner.

Section 31.

A. T. 757. There are shallow wells around here. Water was within 4 feet of surface on June 10, 1896.

Section 34.

1900 N., 500 W. Total depth 10 feet. A. T. 780. Two or three wells (one of them used to be a spring), all went dry in the summer of 1895.

1060 N., 50 W. 27 feet deep. A. T. 834. This well never went dry. This well is on top of a hill; near by are undrained hollows on the hill, and water standing in them.

Section 35.

460 N., 1850 W. Total depth, perhaps, just to rock, 47 feet. A. T. 798.

Sigel Township (T. 16 N., R. 14 E. L.).

In this township there are large surface deposits of sand or gravel in connection with the Forest Beaches so that deep wells have not been found necessary yet, but except at the extreme east side possibly it will be possible to get water in the sandstones which occur in the first hundred feet of the underlying rock. There will be no flows and the deeper water will be somewhat salty. In this township it will not be improved by going deeper as in Chandler.

Sand Beach Township (T. 16 N., R. 15 E.).

Section 5.

100 paces W., 20 N.

20 N., 100 W. SO_4 low, Ca low, Cl strong. Depth to rock 73, total depth 82 feet. A. T. 700.+ J. Gerstenschlager's well. 5 feet shale and 4 feet solid.

Section 18.

40 rods N., 40 rods W. SO_4 low, Ca low, Cl strong, as at Cowpers. Depth to rock 48 feet, total depth 100 feet. A. T. about 730. This well passed through shale 6 feet, slate 2 feet, limestone 2 feet, shale and sandstone 42 feet. R. A. Brown, owner.

250 N., 250 W. of N. W. corner of 19, half way from Brown's to Cowpers. Ca low, Cl med., SO_4 low. Depth, just to rock, 22 feet.

Section 19.

N. W. corner. Ca low, Cl med., SO_4 low. Depth to rock 6 feet, total depth 12 feet. A. T. 750. Cowper's well, with 6 feet of "grindstone" rock.

Section 25.

640 paces W. of Engert's, Ca low, SO_4 low, Cl strong. Depth to rock 83 feet, total depth 85 feet. A. T. about 650. Jacob Layer, owner. There was a layer two feet thick of sandy shale.

140 W., 80 S. of N. E. corner. Ca low, SO_4 low, Cl strong. Depth to rock 54 feet, total depth 57 feet. A. T. about 640. George W. Engert. This well passed through sandy shale.

Section 12. L. Harbor Beach.

The village is supplied by water works taking water by lake from a 1200 foot conduit near north end of breakwater, described in Huron Times, Friday, Sept. 17, 1897, cost $16,000. Walker system of water supply. Rock is soon reached and is within a few feet of the surface for 2 or 3 miles north and south.

Two deep wells have been put down, fully reported in previous volumes, and discussed in the description of the geological column, and the analyses of waters given above.

(1) Depth 702, 715, 800 to 900. See Geol. Survey of Mich., Vol. III, p. 184; V, p. 80. Sandstone from 650-715.

(2) Geol. Surv. of Mich., V, p. 81. Abstract of record:

Coldwater shales	1-500 feet.
Berea black shale	500-603
Berea grit	603-664
Bedford and Erie shales	664-850
Huron black shale	850-1120
Traverse, i. e., Hamilton shales and limestones	1120-1725
Encrinal limestone?, 15 feet of hard rock at	1400
Helderberg limestone	1725-1920

T. 16 N., R. 16 E. Sand Beach.

Section 30.

600 paces N., 700 W. SO_4 trace, Ca low, Cl high. Depth to rock 24 feet, total depth 65 feet. A. T. 622.+ S. Lincoln, owner. Situated 3.94 miles from Sand Beach on lake shore road.

1950 N., 1400 W., 600 paces E. of the N. W. corner. T. 16 N., R. 16 E. Total depth 18 feet. A. T. 602. Robert Brennan, owner.

660 S., 400 W. of the N. W. corner. Sec. 30, T. 16 N., R. 16 E. Depth to rock 16 feet, total depth 22 feet. A. T. 622.+ SO_4 low, Ca low, Cl medium. Ingall, owner. This well is through sand and clay to rock, then in 2 feet sandy shale. The water is not so hard but that it can be used in washing. There is 7 feet of water in the well. This well is situated 3.55 miles south from Harbor Beach on Lake Shore road.

200 paces E. of the N. W. corner. Depth to rock 30 feet, total depth 50 feet. A. T. 682. SO_4 low, Ca low, Cl high Davis. Chas. Keane, owner. This well is through sandy shale.

1890 N., 1800 W. A well 300 feet from road.

Fairhaven Township (T. 17 N., R. 9 E.).

Section 36. Bayport.

420 feet W. of center line, 946 feet N. of center line.

1358 N., 1159 W. Cl med., SO_4 med. Sp. Wt. 1.0017. Total depth 328. A. T. 590 ± Located below the bluff and between the hotel and the bay. Water was found in a coarse grey sandrock, and rises above the surface and forms a flowing well. The temperature of the flow is 47°, "uniform winter and summer." Analyzed by Prof. A. B. Prescott. See p. 136.

1400 N., 1500 W. Total depth 338 feet. This is similar to the one above.

Near the W. line of E. ½ of S. W. ¼. A. T. 602. Webber's No. 3 well. This well passed through 4¼ feet of "firestone," so called because used for hearths; 3⅔ feet limestone; 15 feet sandstone, sample grey white, fine grained at 12 feet 9 inches; 4 feet sand and limestone, light "cement bed" shale and sandstone; 23½ feet shale with occasional mixture of sandstone.

Laurence Smith's well. Total depth 30 feet. These wells are through rock, 2½ feet surface, 10 feet limestone, 4 feet sandstone.

Stoll's well. Depth to rock 18 feet, total depth 40 feet. Rock powder like milk at 40 feet. Cf. records above. This must be in the shale formation and is probably a gypsum streak.

1075 N., 520 W. 200 feet N. of center line. A. T. 612. From 264 to 350 was water bearing sandrock; from 350 to 453 "red stuff, stopped in it." Cf. Sovereign's well on Sec. 30. Lake Tp. There is another report of the same well as follows:

Depth to rock about 30 to 50 feet, total 500 to 600 feet. The well passes through soapstone, sandstone, limestone and gypsum and shows some fool's gold (pyrite). At 250 feet they struck good water which rose to within 2 feet of top of casing. The first rock is sandstone.

1550 N., 650 W. Total depth 80 feet. A. T. 627. This well begins in sandstone at the house.

Depth to rock 20 feet, total depth 100 feet. A. T. 592 feet. This well is at the engine house.

Depth to rock 30 feet. A. T. 602. This is at the barn.

Pyrite was found near Bayport at 44½ and at 94½ feet.

All the above wells were on L. P. Mason's place.

665 feet N. of center line and 660 feet W. of center line. 1250 N., 1250 W. Depth to rock 3 feet, total depth 15 feet. A. T. 600. This well is said to be in sandstone, but from outcrops near by probably also passes into limestone. The analysis is No. 10, by Prof. R. C. Kedzie, given on p. 136. It is the Bayport springs as advertized, under the Arbor.

640 N., 50 W. Total depth 6 or 7 feet. A. T. 630. This well is in rock and can be dipped dry.

260 N., 50 W. A. T. 625. This well is to rock, but it is shallow.

1250 N., about 1350 W. At Bayport R. R. station. About 19 feet deep. This well has been analyzed by Prof. Prescott, analysis No. 9 on p. 136; it is somewhat more strongly mineralized than the Bayport springs and being a little deeper probably penetrates the limestone more.

900 N., 250 W. Depth to rock 0, total depth 47 feet. A. T. 593 (11.16). This is W. L. Webber's No. 4 well.

10½ feet of fire stone (as in hole No. 3, and the stone in the railroad cut, used by early settlers instead of fire brick for lining their arches, whence the name). 15 feet sandstone, 8½ feet superior coarse sandstone, 1½ feet shale, 7 feet whetstone (fine) for honestone, 4½ feet shale. This hole begins very close under the outcrop of Lithostrotion beds near by. Sp 19170-19173.

Caseville Township (T. 17 N., R. 10 E. L.).

Section 1.

1260 N., 1950 W. This well is about 17 feet deep and is not cased, but has plenty of water. SO_4 probably strong. Cf. Sec. 2.

50 N., 540 W. Total depth 16½ feet. A. T. 600. The water is not salty, but gives a white kettle scale. Cl low, SO_4 trace.

50 N., 1580 W. A. T. 610. Owner, J. A. Holmes.

800 N., 1950 W. Depth to rock 20 feet, total depth 178 feet. A. T. 607. J. Adams, owner; Mozier and Erb and later D. Bullock, drillers. At 93 feet they struck

salty water and at 96 feet gas indications. Bullock cased to 112 feet and at 178 feet found fresh water. This is the house well.

The one at the barn is dug 24-26 feet, then tubed. The first water is probably at 20 feet or 25 feet. Cf. Libby's well across the way.

Section 2.

800 N., 50 W. SO_4 probably strong. Total depth (just to rock?) 21 or 23 feet. A. T. 609. Libby, owner. This well is "to plaster rock."

1800 N., 50 W. SO_4 strong. Total depth 14 feet. A. T. 608. J. Gardner, owner. This well is to rock.

Section 10.

50 N., 280 W. There is no SO_4 in the water. Total depth 32 feet, dug 8 feet and drilled 22 feet. A. T. 617.

740 N., 50 W. SO_4 strong. Depth to rock 22 feet, total depth 26½ feet. A. T. 617.

Section 11.

50 N., 500 W. A. T. 617. This is a "mineral" water, that is SO_4 strong. Total depth about 30 feet. 14 or 15 feet was dug and 10 feet drilled.

Section 12.

Around here it is 26 to 30 feet to rock. At 10 feet the water shows SO_4 0 and at 23 feet SO_4 trace.

50 N., 1400 W. Total depth of well 9 feet. A. T. 612.

200 N., 1300 W. Total depth 16 feet. A. T. 612. This is not a drilled well.

50 N., 240 W. SO_4 strong and Cl strong. Total depth 27 feet. A. T. 619. This well was bored with an auger, and the water came up with a rush when it struck rock. There was 16 feet of water in the well.

Section 13. (Hayes.)

1460 N., 1950 W. A. T. 612. C. F. Leipprandt, owner. Depth to rock 30 feet, total depth 55 feet. This water is not salt to taste but contains SO_4 strong.

1500 N., 1900 W. Depth to rock 28 feet, total depth 100 feet. A. T. 610. The water is very salt to taste and is also strong of SO_4. The owner makes his own family salt and frees it from iron by setting it in the sun for 24 hours.

1580 N., 1900 W. SO_4 0, not salty tasting. A. T. 610. This is a flowing well. Total depth 278 feet. At about 228 feet very white sandstone. It is cased for 260 feet. Three days of north wind will make the head rise a foot, and three days of south wind will make the head fall a foot. This is a more than usually accurate observation, as Mr. Leipprandt is an observer of the State Weather Service.

50 N., 540 W. SO_4 strong, Cl med.+ Total depth, just to rock, 25 feet. A. T. 620. W. Steinmann, owner. Sp. Wt. 1.005. The water in this well stands at five feet from the surface.

1950 N., 1300 W. This well is not drilled. A. T. 615.

1950 N., 560 W. Total depth about 30 feet. A. T. 617. This is a dug well.

1950 N., 240 W. A. T. 619. This well is slightly mineral and is 16 feet deep.

Section 14.

600 N., 1950 E. The water is hard, SO_4 strong. Total depth 20 feet. A. T. 619. This well is at barn and was dug.

There is a well at the house which is only 12 feet deep and the water is not so hard.

600 N., 1700 E. Total depth 52 feet. This well was dug for 19 feet and passed into two feet of blue clay.

1840 N., 1100 W. SO_4 strong. Total depth 26 feet. A. T. 617. Geo. Anderson, owner. This well was dug for 16 feet and drilled for 10 feet.

100 N., 400 W. Cl med. Total depth 35 feet. A. T. 617. This well was drilled for some 16 feet. Chas. Stewart, owner.

150 N., 400 W. SO_4 low, Cl low. Total depth 40 feet. This well was hand drilled.

940 N., 50 W. This water is good. Total depth 12 feet. A. T. 617. M. C. Gregory, owner.

Section 15.

1950 N., 420 W. A. T. 617. This water is not very good. Depth of wells 6 and 11 feet.

Section 16.

S ½ of N. W. ¼ of S. E. ¼. This is a salt spring found by F. Lawrence.

50 N., 780 W. Cl strong, SO_4 strong. Total depth 18 feet. A. T. 600. They found gypsum in digging this well, Sp. 19159.

Section 21.

50 N., 780 W. A. T. 612. This is a shallow well and the water is about 6 feet below surface. Another well near by has SO_4 0. Total depth about 27 feet.

There is a well 7 feet deep at the house and one 11 feet deep at the barn which contains only two feet of water. It is said to be 37 feet from ground to bed rock hereabouts.

880 N., 50 W. SO_4 strong. Total depth 40 feet. A. T. 619. This well was dug 12 feet and drilled to 40 feet.

Section 22.

1240 N., 1950 W. Total depth 9 feet. A. T. 620. T. D. Smith, owner.

1760 N., 1950 W. Total depth about 40 feet. A. T. 620. This well was dug 20 feet and drilled the rest of the way.

1050 N., 1300 W. Depth to rock 30 feet, total depth 242 feet. A. T. 619. This well has about 50 feet of casing. There was good surface water at 28 feet, but the water now is salty. Hon. J. J. Murdock, owner. At the bottom of this well there is about 40 feet of white sandstone; it also passes through limestone and soapstone, but gray and white sandstone are supposed to make up half the depth. The water would be better if tightly cased 200 feet.

1050 N., 1820 W. Total depth 6 feet. A. T. 620. This is a dug well.

1840 N., 1420 W. Total depth 3 feet. A. T. 610. This is a spring on the side of the well marked stream valley.

1950 N., 50 W. A. T. 619. This well is 10 to 20 feet, and is a dug well.

400 N., 50 W. A. T. 617. SO_4 trace. (1) 73 feet deep. There was six or seven inches of hard rock struck in this well, which was drilled with hand drill. It must be right in a channel. (2) Total depth 50 feet.

Section 23.

N. E. quarter of N. W. quarter. 1700 N., 1050 W. SO_4 strong, Cl strong, Sp. Wt. 1.009. Total depth, just to rock(?), 50 feet. A. T. 617. J. Newman, owner. This well was put down in July, 1896.

1750 N., at the barn there is a well 40 feet deep. The water contains SO_4 med., Cl med.

400 N., 1950 W. Total depth 18 feet. 11 feet of this was drilled. A. T. 617.

S. E. quarter of S. E. quarter, 50 N., 200 W. A. T. 617. The water is salt. Cl med., SO_4 med.

1400 N., 50 W. SO_4 strong, Cl low. Total depth 50 feet. A. T. 617. D. Schubach, owner.

Section 24.

400 N., 50 W. SO_4 trace. Total depth 12 feet. A. T. 623. This well contains fresh water. Schram, owner.

Section 25.

1950 N., 960 W. SO_4 strong, Cl strong. Total depth about 42 feet. A. T. 622. This well was dug for 10 feet and 42 feet drilled by hand. A strip of country ½ mile N. and S., and more than a mile east and west has yielded bad, i. e., salty and sulphated water.

1950 N., 1360 W. Total depth 40 feet. A. T. about 620. (1) Cf. This is salt (said to be the most so in this area). (2) Depth 14 feet, said to be fresh.

1580 N., 1950 W. A. T. 618. This water is salty. Total depth 49 feet.

800 N., 1950 W. SO_4 strong, Cl low. Total depth 42 feet.

Section 26.

840 N., 1950 W. SO_4 strong. Total depth 14 feet. A. T. 617. J. Barr, owner. There were large blocks of gypsum found in the drift.

400 N., 1850 W. Total depth 40 feet. A. T. 620. Old drilled well now closed up.

(2) This well was dug 18 to 20 feet and is now down to 25 feet and is to be drilled farther. In the drift a loose piece of pyritiferous rock with spirifers was encountered (some of the Soule limestone) hand drilled.

800 N., 50 W. SO_4 strong, Cl low. Total depth 51 feet. A. T. 620.

Section 27.

A. T. 621. Harry Barr, owner. Gypsum was found at 25 to 30 feet.

Section 28.

280 N., 1950 W. SO_4 strong. A. T. 622. This is a dug well.

950 N., 1860 W. SO_4 strong. A. T. 617.

750 N., 1200 W. SO_4 strong. Total depth 50 feet. A. T. 620. J. P. Smith owner. This well was dug for 10 feet, and drilled for 40 feet.

950 N., 120 W. SO_4 0. A. T. 620. This is a shallow well at house.

1100 N., 1050 W. A. T. 619. 8 feet deep at house.

1100 N., 1150 W. Total depth less than 40 feet. A. T. 619. This well is in quicksand and is both dug and drilled.

950 N., 1300 W. Total depth 8 feet. A. T. 620.

1050 N., 1200 W. SO_4 trace. A. T. 622. This is a dug well 18 feet deep.

1050 N., 1300 W. Total depth 37 feet. A. T. 620. This well passed through a boulder 3 feet thick with quicksand beneath.

Section 29.

50 N., 400 W. Total depth 17 to 18 feet. A. T. 620.

980 N., 50 W. Total depth 40 feet, 20 feet dug and 20 feet drilled. A. T. 612. This well had a great flow. The water was very hard and not good for cooking. SO_4 strong.

950 N., 1350 W. SO_4 low. Total depth 20 feet, not to rock, in blue clay. A. T. 607.

Section 30. (Old Bayport.)

Depth to rock 7 feet, total 2,000. A. T. 590.

See analysis on p. 136; about 550 feet below surface it is stopped off, and the head is +15 feet or 20 feet; at 600-700 the head is even greater, +25 to 30 feet, but the water is charged with salt.

Total depth 2000. This is the Old Bayport well and is over 2000 feet deep. It was cleaned by J. Coreyell. W. L. Webber, Dec. 3, '97, reports that in 1873-74 the well was put down for salt. It failed soon after and W. L. Webber bought the property. John Coreyell redrilled it and got him to recase. At 500-800 feet there was a flow so strong as to equal 32 feet head. At present the head is almost 10 feet. When stopped off at 730 feet according to one account, it was still salty, when stopped off at 500 to 550 though it was strongly mineral it was not salt. This is, therefore, probably near the line between Upper and Lower Marshall. J. Coreyell reports the record to be about the same as at Caseville, but with more limestone, as follows: (From memory.)

	Feet.
To top of rock	7
Limestone	3-4
Very hard limestone, then sandstone	12-15
Very large flow of water	250-260
Beginning of 135 feet of sandstone (Napoleon L.)	270-280

At 600 perhaps a streak of plaster (probably not, he is thinking of the Saginaw valley. L.).

At 900. Only 10 feet of salt rock which pinched out as compared with Caseville. (Conglomerate I of Point aux Barques lighthouse? L.)

At 1900. Stopped in shale with no sufficient flow of brine.

Section 31.

950 N., 1440 W. Total depth 15 feet. A. T. 622. This well is through solid clay. S. M. Fuller.

950 N., 1000 W. This is a similar well, John Severn.

260 N., 20 W. Total depth 61 feet. A. T. 630. There are 5 feet of sandstone at the bottom of this well, limestone at top, water 20 feet from top of ground. There are five other wells on this place. Cf. records of Sec. 5, T. 16 N., R. 10 E.

Section 32.

50 N., 900 W. A. T. 637. This well has good water.

20 N., 300 W. This well is about 10 feet deep. There is 4 feet of sand in the well, the rest is clay and the water is poor.

50 N., 1600 W. Depth 15 feet. A. T. 630. This well is through clay? and contains water all the year.

50 N., 1360 W. Total depth 10 feet. A. T. 630. This well runs dry.

1950 N., 400 W. Depth to rock 48 feet, total 62 feet. A. T. 626. Plenty of water, but SO_4 strong. This well is owned and drilled by Byron Lutson. The water is said to come up white and creamy.

1050 N., 1420 W. A. T. 626. This well is not drilled.

1050 N., 800 W. SO_4 trace. This well is not to rock at 40 feet depth. A. T. 625. It was dug 20 feet and had 12 feet of water in it.

1050 N., 800 W. SO_4 strong. Depth to rock 40 feet, total depth 50 feet. A. T. 625.

Section 33.

1050 N., 1440 W. SO_4 0. A. T. 622.

950 N., 1440 W. Total depth 7 feet. A. T. 622.

50 N., 1700 W. A. T. 645. This was a new well July 24, 1895. At 41 feet it stopped in quicksand.

Section 34.

50 N., 320 W. Total depth to rock 35 feet. A. T. 622. SO_4 med. Much white kettle scale. This well used to flow. The water comes in the rock. This well was hand drilled.

Section 35. (Berne).

2 miles north of Moeller of 2-16-10, i. e., N. W. of 35. A. T. 622.

"There is plenty of water and it rises to the top of the well. This well was dug 8 feet, and drilled 20 feet, into a cement rock like soapstone blue and soft, the blue soapstone was on top of the water-bearing rock."

1300 N., 1950 W. Total depth 10 feet. A. T. 620. This is not a drilled well.

50 N., 800 W. Total depth about 50 feet. A. T. 627.

50 N., 800 W. This well is about 35 feet deep. A. T. 627. There is plenty of water just above rock, at 28 to 30 feet in Berne village near south quarter post.

A. T. 627. Depth 29 feet and cased. H. Dominis, owner. Well at mill 75 to 80 feet deep.

1200 N., 50 W. SO_4 med., Cl trace. Total depth, just to rock, 39 feet. A. T. 627. This well is hand drilled.

860 N., 50 W. Depth to rock 30 feet, total depth 34 feet. A. T. 627. The water rises to about 7 feet below surface.

Section 36.

1380 N., 50 W. Total depth, just to rock, 43 feet. See Sec. 36-17-10. A. T. 632.

50 N., 900 W. Total depth, just to rock, 35 feet. A. T. 636. The water rises to within two feet of the ground.

50 N., 1000 W. A. T. 632. This is a similar well, at the house, which used to flow.
1800 N., 1950 W. Cl low, SO_4 0. Depth to rock 70 feet, total depth 78 feet. A. T. 622. (1) Is a shallow well at the house. (2) At 25 feet struck a rock but did not strike rock "for good" until 70 feet.

Chandler Township (T. 17 N., R. 11 E. L.).

Gould's well is said by Hartman to have found gypsum from 70 to 72 feet, and left off in it. Cf. Sec. 16 Chandler.

Section 2.

0 N., 80 W. Total depth, just to rock, 25 feet. A. T. 627.
0 N., 1320 W. SO_4 none, Ca low, Cl low. A. T. 629. This well is 25 feet deep, probably.

Section 3.

2000 N., 1640 W. A. T. 627. SO_4 low, Ca low, Cl traces. D. Wm. Riddle, owner. Total depth 64 to 68 feet. Abundant supply of water.
1900 N., 600 W. SO_4 trace, Ca and Cl low. Fe present. D. Depth to rock 29 feet, total depth 275 feet. A. T. 627. J. Lonsberry, owner. Wm. Church, driller. This well was drilled in 1895 and water rises to about 10 feet of surface. This well passes through sandstone rocks, not very different all the way down.
1900 N. Depth to rock 20 feet, total depth 22½ feet. This well is in the same vicinity.

Section 4.

50 N., 1280 W. A. T. 632.
50 N., 1060 W. A. T. 640. SO_4 0, Cl trace.
50 N., 200 W. A. T. 640. This is a shallow surface well on an 8 foot ridge.
1950 N., 1640 W. Depth to rock 40 feet, total depth 185 feet. A. T. 620. Sandstone was struck at about 80 feet. Cl 0, SO_4 low. The water rises to within 2 feet of the surface, at 130 feet it stood 6 feet above the surface.
1950 N., 820 W. Total depth 46 to 56 feet.

Section 5.

50 N., 1440 W. A. T. 627. This is a well that they dip water out of.
50 N., 260 W. (1) Cl low, SO_4 0. A. T. 627. Total depth 23 feet. (2) Cl med., SO_4 low. Depth to rock 23 feet, total depth 60 feet. This well was dug 23 feet and then hand drilled. (3) SO_4 low, Cl low. This well fell into the one above. It was down to sandstone and the water rose four feet from the surface.
1000 N., 50 W. Depth to rock about 20 feet, total depth about 90 feet. A. T. 620. This well is at the school house.
200 N., 1700 W. A. T. 620. Cl strong, SO_4 brackish, and so is a spring nearly on the section line. This well is about 25 feet deep. T. B. Woodworth, owner.

Section 6.

1950 N., 820 W. SO_4 0. Total depth 23 feet. A. T. 612.
1950 N., 220 W. This well is not drilled and is only 12 feet deep. A. T. 612.
400 N., 0 W. A. T. 615. This is a salt spring.
50 N., 600 W. Cl 0, SO_4 trace. A. T. 615. Total depth 18 feet. This is a persistent spring and has plenty of water.
50 N., 1840 W. A. T. 615.

Section 7.

1950 N., 1380 W. Total depth 303 feet. A. T. 617. Cl strong, SO_4 strong. This well has 250 feet of 1½ inch casing, which is leaky and lets the salt down on the sandstone, but the water is fresher after pumping. James McCoubrie, owner. Drilled by O. & W. Church.
At 303 feet there was grindstone, and white stuff at about 200 feet. Salt water was struck at top of rock, and there was also a smell of kerosene, at 280 feet there was 25 feet of white sandstone.
1950 N., 1000 W. A. T. 620. This is a dug well 8 feet deep and contains plenty of water.
1950 N., 1700 W. A. T. 617.

Section 8.

800 N., 1950 W. Cl low, SO_4 strong. Total depth 30 feet. A. T. 622. E. Gericke, owner.
1950 N., 1740 W. SO_4 low. This well is 18 feet deep. A. T. 627.
1950 N., 1200 W. Cl low, SO_4 strong. Total depth 25 feet. A. T. 622.
1950 N., 500 W. Total depth 24 feet. A. T. 627.
1900 N., 425 W. SO_4 strong, Cl low. This well has a strong flow and its temperature is 49½° F. Total depth 18 feet. A. T. 625.
740 N., 50 W. A. T. 640. This is a dug well.

Section 9.

1950 N., 1800 W. Cl low, SO_4 trace. A. T. 630.
1950 N., 1400 W. Total depth 24 feet. A. T. 635.
1500 N., 50 W. A. T. 642. This well is 32 feet deep and is dry sometimes because it has only surface soakage.

50 N., 122 W. Cl trace +, SO_4 mod. This is a surface well at the house. There is also a well at the barn.

Section 10.

N. E. Cor. of N. E. quarter of Sec. 10. Depth to rock 37 feet, total depth 40 feet. A. T. 657. John Quinn, owner; A. W. Rapson, driller. This well was dug to rock through hard blue clay. The rock is soapstone.

1900 N., 1400 W. (about). Depth to rock 37 feet, total depth 37 feet. A. T. 650. Ca low, Cl none, SO_4 low, Fe present in considerable amounts. D.

1500 N., 1950 W. Cl low, SO_4 strong. A. T. 644.

Section 11.

760 N., 100 W. Total depth 30 feet. A. T. 645. This well is in clay.

Section 14.

2000 N., 420 W. Depth to rock 40 feet, total depth 97 feet. A. T. 613. A. Malphus owner. There is sandstone or soapstone then water. SO_4 0, Ca and Cl low, Fe present. D. There is a dug well at the same place in clay, 18 feet deep. SO_4 none, Ca and Cl less than in deep well. No Fe. D.

50 N., 1400 W. Total depth 12 feet. A. T. 620. There is said to be a spring in the bottom of this well.

Section 16.

W. ½. Depth to rock 12 feet, total depth 217 feet. A. T. 640. At 80 feet a dark water was cased off. It is possible that this well should be in T. 17 N., R. 12 E.

700 to 1200 N., 1900 W. SO_4 strong. Total depth 33 feet to rock. A. T. 640. This is like Maxwell's well on Sec. 17.

1950 N., 800 W. Cl low, SO_4 strong. Depth to rock 35 feet, total depth 74 feet. A. T. 615. (1) This well was drilled by Hartman and Hill of Bayport. (2) This is a dug well.

Section 17.

50 N., 920 W. SO_4 strong, Cl med. Total depth 26 feet. A. T. 636. Alex Maxwell. Water burst in at the bottom of this well.

? N., 100 W. A. T. 640. Frank McArdle, owner. This is the same in quality as Maxwell's well.

Section 18.

50 N., 640 W. A. T. 627. This is a surface well.

1950 N., 1620 W. SO_4 strong, Cl strong. Depth to rock 28 feet, total depth 28 feet. A. T. 620.

Section 19.

1950 N., 640 W. A. T. 627. Total depth about 16 feet. This is a surface well.

50 N., S. ½ of S. E. ¼ of Sec. 19. Total depth 40 feet. A. T. 627. This well is hand drilled and the water is bad, i. e., strongly sulphated. Fisher, owner.

Section 20.

200 N., 50 W. SO_4 0. This well is dug and is 14 feet deep. A. T. 642.

1950 N., 920 W. SO_4 strong, Cl med., "like the well in Sec. 17." About 26 feet to rock, total depth about 26 feet. A. T. 636. J. Drummond, owner.

1990 N., 1920 W. Depth to rock about 20 feet, total depth about 20 feet. A. T. 626. Thos. Maxwell, owner. This well is similar to A. Maxwell's on Sec. 17.

Section 21.

1000 N., 1950 W. Total depth about 50 feet to rock. This is a dug well, but was once drilled. It has no water now.

1950 N., 780 W. Total depth 24 feet. A. T. 640. This is a dug well. There are no drilled wells nearby.

Section 23.

240 N., 1060 W. Total depth 214 or 217 feet. A. T. 640. Mrs. Harvey, owner. Mozier, driller.

Section 24.

1440 N., 1050 W. SO_4 trace, Cl low. Depth to rock 12 feet, total depth 100 feet. A. T. 632. At 12 feet a thin bedded, blue-brown, slightly bituminous fetid fossiliferous limestone or cement rock, as seen in creek, was struck; below this was soapstone rock (arenaceous, blue, ripple-marked, micaceous shale) and about 14 feet of sandstone at the bottom, 86 to 100 feet, i. e., the Napoleon or Upper Marshall.

1300 N., 1050 W. Cl 0, SO_4 low. Depth to rock about 20 feet, total depth 225 to 250 feet. A. T. 640.

950 W. SO_4 med.+ Cl low. Depth to rock 20 feet, total depth 80 feet. A. T. 620. This is Mr. Cody's old well which was only 14 feet deep at first. It passed through a few feet of (limestone) cement rock, then soapstone, and goes only about 2 feet in sandstone.

340 N., 950 W. A. T. 642. (1) Total depth about 200 feet. This well has 20 to 22 feet of casing. It passed through, first, plaster rock, then mainly all white sand-

stone. This well was at first drilled to 133 feet and it flowed freely at this depth, but when I. Heaton's well "broke loose" two years ago, on Sec. 26, this well went dry. (2) A dug well nearby showed plaster (gypsum).

50 N., 1060 W. SO_4 med.+ Cl trace. Total depth 100 feet. A. T. 642. This well has 15 to 22 feet of casing.

50 N., 1070 W. Total depth 22 feet. A. T. 642. The water in this well is much harder.

Section 25.

E. half of S. W. quarter. Depth to rock 20 feet, total depth 25 feet. A. T. 662. S. Shaw, owner.

400 N., 1050 W. Total depth 26 feet. A. T. about 662. This well was dug and blasted through plaster.

400 N., 950 W. Total depth 177 feet. A. T. 662. This is good water. It will make a suds, but the water is hard.

700 N., 1050 W. Total depth 40 feet. A. T. 660.

750 N., 950 W. Depth to rock 20 feet, total depth 140 feet. A. T. 660. This well used to flow but now the water comes close to the top. When it flowed the water was softer. This is significant probably; the flow came from the Napoleon, the Upper Marshall sandstone, and dissolved more or less gypsum on the way.

1950 N., 560 W. A. T. 650. This is probably a drilled well, the water rose to the surface.

900 N., 1950 W. Cl low. Total depth, just to rock, ? 60 feet. A. T. 652. F. Gould, owner. The cost of this well was $60.00. Mosher and Erb, drillers.

1½ miles south of Soule. Gershom Wilson Smith, owner. This well is said to have passed through gypsum on top of cement.

Section 26.

1720 N., 940 W. I. Heaton, owner. The water broke out from this deep drilled well around the casing and made a spring in the river bank and stopped adjacent flowing well.

1950 N., 1400 W. Total depth 18 feet. A. T. 640. This is a dug well. It is also a spring in the side of the river valley.

1950 N., 1950 W. Total depth 30 feet. A. T. 642. This well was nearly dry in summer of 1895.

600 N., 1950 W. Total depth 153 feet, dug 20 feet. A. T. 652.

50 N., 920 W. A. T. 567. SO_4 strong, Cl med. Total depth 90 feet. 85 feet dug or cased. At first the water was salty, then cased off, but it is still strongly mineral.

Section 28.

640 N., 1950 W. Depth to rock 60 feet, total depth 157 feet. A. T. 647. The water is cathartic, strongly mineral and turns tea black, i. e., Fe strong, SO_4 strong, Cl med. +, Mg present, Sp. Wt. 1.002. This well passes through blue and black rock and at 120 feet strikes mineral water.

Section 30.

Probably S. ? E. quarter of S. W. quarter. A. T. 632. Total depth 120 feet.

1040 N., 1950 W. A. T. 627. SO_4 strong, Cl strong. The water is poor. Sp. Wt. 1.010. Total depth 22 feet. Newberry, owner.

1950 N., 1500 W. (1) A. T. 627. Cl strong, SO_4 strong. Depth to rock 40 feet, total depth 223 feet. Here are three wells belonging to W. McPherson of Berne. Drilled by Agnew of Fairgrove. At 100 feet was strong salt brine in bluish soapstone, at 200 feet black sandrock, water not so salty. At 210-223 pure white sandrock. It is now packed down at 130 feet, but is still salt (probably not packed well or low enough). Sp. Gr. 1.032. (2) Total depth 10 feet. (3) A. T. 625. Depth to rock 28 + feet, total depth 140 feet. The water was salty and was stopped up. This well was cased 28 feet, but not to rock. The well was muddy and went to 140 feet. (4) The water in this well is brackish, Sp. Gr. 1.003, total depth 22 feet.

Section 31.

1280 N., 1950 W. SO_4 strong, Cl low. Depth to rock 45 feet, total depth 45 feet. A. T. 632. W. Eichler, owner. The water came out of "soapstone."

1380 N., 1950 W. Total depth just to rock 43 feet. A. T. 632.

1380 N., 1900 W. SO_4 strong, Cl trace. Total depth 150 feet. A. T. 632. H. Bean, owner.

1860 N., 1950 W Depth to rock 51 feet, total depth 56 feet. A. T. 630. SO_4 strong, and at more than 60 feet depth there would be salt water. This well is through soaprock.

50 N., 240 W. SO_4 strong, Cl low. Sp. Wt 1.006. Depth to rock 54 feet, total depth 165 feet. A. T. 640.

Section 32.

50 N., 1780 W. SO_4 med., Cl low +. Depth to rock 63 feet, total depth 129 feet. A. T. 679. The other wells nearby are said to be deeper, i. e., about 10 feet in sandrock.

50 N., 1280 W. SO_4 med., Cl low. Total depth 140 to 145 feet.

50 N., 100 W. A. T. 645. This is a dug well, total depth about 30 feet.

Section 33.

100 N., 1950 W. A. T. 649.

50 N., 1480 W. A. T. 651. SO_4 0. (1) Total depth 7 feet. This was dug through gravel. (2) Total depth 14 feet. Gravelly.

50 N., 740 W. Total depth 12 feet. A. T. 650. This well is not to rock.

1950 N., 500 W. Total depth 33 feet. A. T. 650. This well is in sand and gravel.

1950 N., 1400 W. SO_4 trace, Cl low. Total depth 80 feet. A .T. 650. Down to 45 feet hard gravelly soil, 15 feet quicksand, 20 feet gravel. This well is piped to 80 feet.

50 N., 700 W., SO_4 0, Cl low. Total depth 15½ feet. This well is on a stony clay (till) rise.

Section 34.

Norton, owner. The water was very salt at first, then they drilled deeper.

1730 N., 90 W. Depth to rock 46 feet, total depth 250 feet. A. T. 642. This well passed mostly through slate, but went 18 feet (232-250) in sandrock. Olmstead, owner. The water is good and flowed freely.

Section 35.

10 N., 50 W. Depth to rock 20 feet, total depth 190 feet. A. T. 652.

Section 36.

1950 N., 1000 W. Depth to rock 20 feet, total depth 40 feet. It is 20 feet to rock with gypsum in the blue clay at 15 feet and in layers and great chunks just above the rock.

	Feet.
Cement rock	4
Gypsum	8
Hard rock	4
Gypsum	4

This well stopped in slate. There is generally a sandstone at 80 feet. The water was very hard and gypseous.

Meade Township (T. 17 N., R. 12 E. D.).

Section 2.

0 N., 720 W. Depth to rock 40 feet, total depth 40 feet. A. T. 693. This well is down to sandstone and belongs to Arnold. The well at the old saw mill on main road struck rock at 12 feet.

Section 3.

2000 N., 820 W. Depth to rock 30 feet, total depth 30 feet. A. T. 658. This well is not quite to rock.

2000 N., 1900 W. Depth to rock 20 feet, total depth 28 feet. A. T. 647. H_2. SO_4 none, Ca medium, Cl trace.

Section 4.

2000 N., 1220 W. Total depth 22 feet. A. T. 631. This well is to gravel.

Section 5.

1000 N., 2000 W. SO_4 none, Ca and Cl low. Depth to rock 8 to 18 feet, total depth 65 feet. A. T. 644. M. Dibb, owner.

SO_4 none, Ca and Cl trace. Depth to rock 6, total depth 20 feet. At the house of same owner, rock seems like a thick bedded compact sandstone. On the other side of the road rock at 6 feet, 14 or 15 feet drilling gives good water. The rock is very close to the surface three miles south of this place.

Section 6.

680 N., 0 W. SO_4 none, Ca and Cl traces. Depth to rock 4 feet, total depth 40 feet. A. T. 632. M. E. Parsonage, owner. Rock found in post holes in front of house at four feet from surface.

Section 7.

980 N., 0 W. Depth to rock 20 feet, total depth 23 feet. A. T. 651. The other wells in the neighborhood find about the same depth to rock.

Section 8.

920 N., 1950 W. Depth to rock 20 feet. A. T. 649.

Section 12.

2000 N., 1280 W. Total depth 22 feet. A. T. 704. This is a dug well.

Section 14.

S. W. corner. Depth to rock about 40 feet, total depth 60 feet. A. T. 700. Mark Colts, owner.

Section 15. (Napoleon sandstone near the surface.)

1950 N., 1950 W. Depth to rock 5 feet, total depth 6 feet. A. T. 685. This is a dug well and rock is only 2 feet below the surface near by.

1950 N., 1900 W. Depth to rock 4½ feet, total depth 21 feet. A. T. 665. The sandstone is thin bedded and greenish. Rock is also 4½ feet from the surface in the cellar of the house.

Section 17.

1040 N., 2000 W. Total depth 16½ feet. A. T. 642. They struck no rock in this well.

560 N., 2000 W. Total depth 20 feet. A. T. 642. There was no rock in this well.

2000 N., 140 W. Depth to rock 4 feet, total depth 12 feet. A. T. 667. This well passed through one foot of rock, then 12 feet of "clay." There was plenty of water in this well.

2000 N., 440 W. SO_4 none, Ca and Cl trace. Depth to rock 7 feet, total depth 10 feet. A. T. 650. The water in this well was abundant.

0 N., 1840 W. SO_4 trace, Ca low, Cl trace. Depth to rock 10 feet, total depth 24 feet. A. T. 658. 18 feet of this well was drilled by hand. This is a surface water.

In a prospecting hole in Sec. 19, 2000 N., 1300 W., rock is only 5 or 6 feet from surface, and is dark, compact, soft grained, with conchoidal fracture and weathers to a light color.

0 N., 1100 W. SO_4 none, Ca low, Cl slight trace, Fe present. Depth to rock 1½ feet, total depth 132 feet. A. T. 667. Henry Clark, owner. Mosher and Erb, drillers. This well passes through 5 feet of shell rock, 19½ feet of "cement" (argillaceous limestone), and then soapstone.

50 N., 1900 W. SO_4 none, Cl low. Depth to rock 12 feet, total depth 58 feet. A. T. 650. This well is cased 14 feet and 9 in. There was 20 feet of "cement rock" in this well and sandstone was struck at 52 feet.

Section 19.

There is an outcrop of "cement rock" Michigan series limestone, on Pinnebog river.

20 rods S. of corner. Depth to rock 13 feet, total depth 200 feet. A. T. 660. James Thompson, owner. Erb and Mosher, drillers. This well passed first, through sandstone, then cement rock 18 feet, then soapstone, then hardrock. The water was never pumped out of the pipe and it smells of decaying organic matter.

Section 20.

W. half of N. E. quarter. A. T. 670. W. H. Stephenson's well has grindstone within 3 feet of the surface.

Section 21.

S. E. quarter. Depth to rock 29 feet, total depth 34 feet. A. T. 703. Lackey, owner. This well was dug 25 feet and then drilled 4 feet to rock and then 4 or 5 feet in rock, when the drill dropped and water rose to within five feet of the surface.

0 N., 1140 W. A. T. 712. Depth 14 to 18 feet. E. Stephenson, owner.

2000 N., 1920 W. Total depth, just to rock, 16 feet. A. T. 680.

Section 22.

0 N., 1800 W. Depth to rock 28 feet, total depth 38 feet. A. T. 717.

1975 N., 25 W. SO_4 none, Cl none, Ca very low. Depth to rock 40 feet, total depth 47 feet. A. T. 720. This well is at Filion P. O., 50 feet south of the corner.

860 N., 25 W. A. T. 727. Total depth 40 feet.

Section 27.

0 N., 1160 W. Ca trace, Cl slight trace, SO_4 none. Depth to rock 24 feet, total depth 81 feet. A. T. 710. J. Church, owner. This well passed through sandstone and then shale.

2000 N., 460 W. SO_4 0, Ca traces, Cl low, tastes of Fe. Depth to rock 48 feet, total depth 56 feet. A. T. 717. L. A. Mosey, owner. The water comes to within 9 feet of the top of pipe which does not quite reach rock.

Section 29.

2000 N., 800 W. A. T. 692. SO_4 none, Ca trace, Fe present. Depth to rock 30 to 40 feet, total depth 171 feet. Philip Schad, owner; Erb and Soule, drillers.

Section 32.

2000 N., 640 W. Depth to rock 24 feet, total depth 87 feet. A. T. 692. Max Ritter, owner.

Section 33.

2000 N., 1220 W. Depth to rock 20 feet, total depth 58 feet. A. T. 699.

Lincoln Township (T. 17 N., R. 13 E.).

Section 5.

0 N., 1400 W. Total depth 18 feet. This well is in clay. It is a dug well, there are no drilled wells in this vicinity.

Section 6.

Kinde. A. T. 702.
Mr. Hall, a banker at Bayport, has three wells, 11, 18 and 20 feet deep, respectively, all through blue clay into gravel and they each have plenty of water.

Section 18.

S. E. quarter of S. W. quarter. Desire Fillon has a drilled well.
1400 N., 1950 W. Total depth 20 feet. A. T. 717. This well was dug 3 feet and bored 7 feet, in clay and quicksand. Jas. Penna, owner.
1900 N., 1950 W. A. T. 717. T. Rapson was to bore this well.

Section 19.

1780 N., 2000 W. Depth to rock 37 feet, total depth about 38 feet. A. T. 722.

Section 20.

2000 N., 1580 W. SO_4 none. Ca trace. Cl slight trace. Depth to rock 50 feet, total depth 55 feet. A. T. 717. H. S. Tilt, owner. Water is abundant in this well.

Section 22.

A little W. of the north quarter post. Total depth 21½ feet. A. T. 712. This well was through black loam, very hard red clay, blue clay, sand. It was dug just to sand. After digging the well was left dry, but next morning it had 16 feet of water in it. The water could not run a boiler a week. It had to be blown off for it was red, soapy and foaming. The water rose to 1 foot below the surface.

Section 30.

100 N., 50 W. This is a shallow well, dug 9 feet. A. T. 746.
75 N., 1700 W. Total depth 12 feet. A. T. 745. "This well is like a spring."

Section 31.

112 N., 1950 W. Depth to rock 40 feet or more, total depth 60 feet or more. A. T. 746. The water rises to 7 feet below the surface.

Section 32.

220 N., 1950 W. Total depth 13 feet. This, the old well, had 20 inches of water. The new well was 66 feet deep, and the water rose to 17½ feet below the surface. It was a mineral water, but not as hard as the surface water.

Bloomfield Township (T. 17 N., R. 14 E.).

Section 5.

1680 N., 2000 W. Total depth 30 feet. A. T. 690.? This well is in blue clay.

Section 6.

2000 N., 1580 W. Total depths 11 and 16 feet, in clay. A. T. 697.

Section 14.

20 N., 100 W. Depth to rock 30 feet, total depth 65 feet. A. T. 715. W. R. Stafford, owner. The water in this well is salty.

Section 17.

1250 N., 750 W. (about). Total depth 22 feet. A. T. 709. There are two wells here in clay. Wells in the region to the north are shallow in the clay, but there is as yet plenty of water.

Section 18.

0 N., 1120 W. A. T. 694. Total depth 22 feet. This is a dug well, no rock.

Section 20.

S. W. quarter of Sec. 20. Depth to rock 40 feet, total depth 150 feet. J. W. Kelly, owner. The water in this well is salty and comes to within 1½ feet of the surface. The well passes through 40 feet clay, 20 feet sandstone with water, 20 feet soapstone, 70 feet unknown, blue, hard, "kind of slate," between soaprock and hard rock.

Section 22.

200 E., 400 S. of N. W. Depth to rock 40 feet, total depth 135 feet. W. Wright, owner. A. T. about 732. Water was salty at 80-90 feet. There is no water in this

well now. The well passed through sandstone (shale?) and soapstone. Another report says 50-60 feet to rock, total depth 145 feet.

Rubicon Township (T. 17 N., R 15 E.)

Section 4. Port Hope.

A. T. 610. There is a salty shallow well at the hotel. There were also deep wells for the manufacture of salt.

See Geol. Sur. of Mich., Vol. V, Pt. II, p. 76, an abstract of the record is as follows:

1-16 feet drift.
Coldwater shales:
16-22 feet green micaceous sandstone, outcrops along shore.
22-532 feet blue arenaceous shales with occasional seams of sand rock.
532-533 feet hard rock, pyrite or siderite.
533-687 feet dark-blue shale.
687-716 feet arenaceous shales.
Berea Grit:
716-787 or 800-865 feet coarse whitish sandstone impregnated with strong salt brine.

Section 15.

700 N., 800 W. Total depth 13 to 14 feet in blue clay. A. T. 622.

Section 27.

S. W. quarter of N. E. quarter. Depth to rock 70 feet, total depth 103 feet. A. T. about 610. John Schmucker, owner. SO_4 trace, Ca and Cl low. This well is through blue sandrock. There is not much water and it is apparently from the clay.

3¼ miles W. of this there is reported a salt well. The well was not stoned and was abandoned. There is also a surface well near that of John Schmucker about 12 feet deep.

Section 35.

20 paces E. of shore road, 1850 N., 950 W. Surface well 12 feet deep. A. T. 622. John Hopson, owner.

Section 36.

20 paces E. of shore road, 950 N., 1950 W. SO_4 trace, Ca low, Cl med. Depth to rock 20 feet, total depth 23 feet. A. T. about 612. This well went through one foot of thin sandstone and the drill dropped beneath it. Wm. F. Burley, owner.

Caseville Township (T. 18 N., R. 10 E.).

Section 25.

S. W. of N. E., or Sec. 26, lot 4, perhaps more likely. A. T. 607. It is reported that they went through 40 feet of plaster on Mintline's place.

Near center, Cl 0. A. T. 607. Mr. Corless, owner. This is a dug well.

Section 26.

1950 N., 700 W. A. T. 612. Lot 4. D. Mintline, owner. It is reported that they went through 40 feet of plaster.

Section 35.

(2030 feet) 840 paces N. (2740 feet) 1950 paces W. There are various reports as to the total depth, viz.: 2200, 2300, 2270. (1) The first well of the grist mill was deeper than the rest, and gave a 96% brine and some gas. In this well at 18 feet they struck boulders with sandstone and had about 100 feet of it. The well was put down by Hiram Adams, and was one of F. Crawford's wells, Geol. Sur. of Mich., III, p. 94, 184, 201, V, p. 53. It was 2200-2300 feet down to third salt rock. They had to wash the pans when they used the brine from the various levels below 1800 to 2300 feet every 24 hours and later every 12 hours. Whereas before they only needed to wash every 48 hours to get rid of bittern. This shows the relative impurity of this lowest brine. From 1700 to 1800 was hard sandrock (the Berea Grit), another at 1900, then some clay and a streak of very hard rock with brine again at 2200 feet. This is probably from some horizon below the Genesee or Huron black shale. Compare from 2560 to 2740 in the deep Bay City well, in which the Berea Grit is at 2100 to 2260.

(2) 2300 feet N., 3880 feet W. A. T. 585. Curran Flach and Conley. Total depth 1800 feet.

At 8 feet rock.
At 18 feet sandrock, first casing to 20 feet.
23 feet sandrock.
10 feet blue clay and hardpan.
10-12 feet "hard rocks like flint with boulders," probably cherty limestone.
About "100 feet slate or shale."
About 50 feet gray sandstone.
At (165 feet) about 190 to 200 feet, a seam of coal.?
At about 300 feet black clay as per sample.

At about 400 feet a fine powder, like copper filings, mixed with clay. Casing hard to pull.

750 feet salt rock.

The well is cased to 800 feet (not far enough), shutting off this brine. From 800 feet down was mostly dark grey slate. At 1800 second salt rock. When the casing was pulled the water flowed out at first and even now is only 4 feet from the top.

(3) 1780 N., 3700 W. About 590 feet. F. Crawford, owner. Cf. Rominger III, p. 94, 184, 201. Total depth 1735, 1760, or 1750.

1-900 feet. "Principally through blue shale, sometimes through red shales with no important seam of harder rock in the whole interval." (This is not so.)

At 900 feet. Large body whitish rock with strong brine; "near bottom another supply." C. E. Wright says from 850 to 950 was sandstone, and from 1650 to 1770 sandstone.

J. Coreyell reports 2 to 3 feet bed rock, limestone shell and slate.

At 115-120, first sandstone.

From 125 to 150 sandstone with streaks of shale.

At 900-950 first salt rock, 80°.

At 1750 feet second salt rock, i. e.

From 1680 to 1765 sandstone.

(4) About 1600 N.? in Sec. 26. Total depth 1760. Pigeon River Furnace Company.

950 N., 1000 W. SO_4 strong. Depth to rock 40 feet, total depth 140 feet. A. T. 602. Well at Adams' store. There was a little limestone, then shale most of the way, then bottom in sandrock. The well at his house in Sec. 1-17-10 is about the same. Campau dug gypsum on his place, also something like gypsum was dredged from the river in blocks.

South part of Caseville. Total depth 48 feet. A. T. 607. C. Crawford, owner. There are "several kinds of rock" in the short distance of 48 feet, viz., "limerock, shale, sandrock, gypsum."

1800 N., 80 W. Total depth 14 feet. A. T. 612. This well is in quicksand.

Lake Township (T. 18 N., R. 11 E.).

S. E. quarter, 50 W. Total depth 12 feet. A. T. 610. This well is not to rock.

Section 18.

Lot 1, close to lake about 300 N., 100 W. Depth to rock 9 feet, total depth 100 feet or more. A. T. 690. G. M. Stewart, owner. D. Bullock, driller. 0 to 100 sandstone, then black slate, soapstone and red stuff, according to driller, or another report says all sandstone. Mr. Flach thinks that 4 or 5 inches of coal were struck, i. e., black slate, but Mr. Dufty says it was all sandstone and no coal.

Section 23.

50 N., 50 W. Total depth 10 to 12 feet. A. T. 624. (2) Depth to rock 15 feet; total depth 30 feet. This well was dug 15 feet and then drilled 15 feet, but they got no water.

S. W. quarter of S. E. quarter. Total depth to rock 4 or 4½ feet. A. T. 612. There is plenty of water in this well.

50 N., 1300 W. Total depth 9½ feet. A. T. 607. W. King, owner.

Section 24.

1780 N., 50 W. SO_4 trace, Ca low, Cl low. Depth to rock 20 feet, total depth 20 feet. A. T. 612. T. Welsh, owner.

Section 25.

1950 N., 1350 W. SO_4 low, Ca low, Cl low, signs of Fe. Total depth 18 feet in rock. A. T. 623.

Over 1000 N., 1950 W. Total depth 40 feet. A. T. 622.

Section 26.

0 N., 260 W. SO_4 none, Ca and Cl trace. Depth to rock 40 feet, total depth 68 feet. A. T. 638. Alex. Champine, owner. J. McLaren and C. Jones, Bay City, drillers.

1320 N., 2000 W. H_2SO_4 trace, Cl trace, Ca low. Depth to rock 27 feet, total depth 37 feet. A. T. 635. This well is first through shell rock (shale), then a harder one.

1950 N., 1360 W. Total depth probably 14 feet. A. T. 610.

420 N., 0 W. Total depth 36 feet. A. T. 632. This well was drilled part way.

1750 N., 1000 W. A. T. 612. Cl trace, SO_4 med. Ed. Sovereign, owner; D. Bullock, driller.

RECORD.

	Thickness.	Total.
Surface	7 feet	7
Black slate, perfectly dry, with coal at 42 feet, and at 60 feet and 12 (?) feet of "sulphur" pyrite, in the middle	80	87
Sandrock light grey	67 ±	154
Iron ore (compare this with the paint rock so often spoken of. Cf. Mauch Chunk shales or Catskill shale, and the Lower Marshall sandstones	100	254

1162 W., 1450 N. Cl trace, SO_4 strong. Total depth 100 feet. A. T. 612. Mrs. McKay, owner.

1100 N., 1400 W. The water is very hard. Total depth 13 to 18 feet. A. T. 607. "River sand" occurs at the surface.

Section 32.

50 N., 660 W. Wm. Dufty, owner. A. T. 622. (1) Depth to rock 40 feet, total depth 202 feet. The water rose at first to 3 feet, now to 20 feet below surface. Cl trace, SO_4 trace. At 40 feet rock, at about 80 feet sandrock, coarse at first, then whiter and finer to the end. (2) Depth to rock 40 feet, total depth 75 feet. Cl low, SO_4 strong. This is in dark slate, never in sandstone. There was a sinkhole near by thirty years ago, filled up with stumps and rubbish, but a second drop took place about 1883, like a well 6 feet across and 20 feet deep. A line of similar holes seem to extend E. S. E. It used to be a salt lick. These sinks are probably over a limestone, possibly gypsum.

Section 34.

80 N., 1820 W. Total depth 28 feet. A. T. 632. R. Gotts' three wells.

Section 35.

1925 N., 820 W. Depth to rock 23 feet, total depth 35 feet. A. T. 629. This well is 150 feet south of road.

2000 N., 1320 W. Depth to rock 26 feet, total depth 29 feet. A. T. 635. This well is opposite the last.

Section 36.

150 N., 1300 W. SO_4 none, Ca low, Cl low. Depth to rock 23 feet, total depth 53 feet. A. T. 637. There is also a dug well 27 feet deep.

Hume Township (T. 18 N., R. 12 E. D.).

1950 N., 500 W. Ca low, Cl low, SO_4 trace. Temperature 46° F. This is not a flowing well. This is probably one of Learned's drilled wells.

Section 10.

1605 N., 450 W. Brackish SO_4 med., Ca med., Cl strong, Fe present. This is an old salt well flowing slightly near Port Crescent. Williams, Eakins and Soule, owners. Hi Adams of Waukesha, Wis., driller.

About 1500 N., 1000 W. Total depth 1250 feet. This is a flowing well. The water is brackish. SO_4 strong, Cl strong, Ca strong, Fe present. Miss Haskell's well "from pipe N. E. of well;" 600 feet to mineral water now flowing; 1250 feet to bottom of salt well.

900 N., 10 W. Depth to rock 18 feet, total depth 20 feet. A. T. 612. Tom Clancy, owner. He has another well which is flowing. Total depth 23 or 29 feet. It was dug 18 feet, drilled 11 feet to a flow, through hard clay. There is no rock in this well, but I think it likely that the water is just above bed rock. Total depth 30 feet.

Carter, owner. This is a flowing well.

Section 11.

Most of the wells here are dug down to bed rock, and then holes drilled farther.

E. half of S. W. quarter. Depth to rock 12 feet, total depth 30 feet. A. T. 612. The water rises to about 8 feet from the top in dry times. John Clancy, owner. This well was dug 12 feet to rock and went 18 feet through grindstone.

950 N., 740 W. There are two surface wells here. Both went dry in 1895 and water had to be drawn from the lake.

1050 N., 840 W. Depth to rock about 22 feet, total depth 43 feet. A. T. 616. Sinclair, owner. 22 feet basin, 21 feet drilled, or another says 20 and 20.

1050 N., 1360 W. Depth to rock 12 feet, total depth 37 feet. A. T. 612. The water supply is constant but not large. This well has a twelve-foot basin to rock, probably shale.

Section 12.

1050 N., 1340 W. SO_4 0, Ca low, Cl trace. Depth to rock 5 feet, total depth 100 or 118 feet. A. T. 624. Ed Ahearn, owner.

950 N., 1260 W. SO_4 0. Ca low, Cl trace. Depth to rock 7 feet, total depth 80 feet. A. T. 628. Henry Conley, owner.

	Thickness.	Total.
Clay	7	7
Then 44 feet rock, no casing	44	51
Then 1 foot blue clay, *i. e.*, shale, but compare section at Hardwood Point	1	52
Rest gravel, etc (*i. e.*, conglomerate)	28	80

950 N., 1760 W. SO_4 0, Ca trace, Cl low. Depth to rock 6 feet, total depth 54 feet. A. T. 627. 14 feet basin. Rock is a soap rock, i. e., shale, hard at first but dissolves away. At 50 feet, sandrock with water, then a black sticky shale. All along this ridge it is but 6 feet to rock while down at the corner it is 18 feet to rock, which is a soapstone and bits of gypsum are reported in it.

1050 N., 1760 W. Depth to rock about 6 feet, total depth 54 feet. A. T. 627. This is similar to wells just south.

950 N., 1900 W. Ca traces, SO_4 low, Cl low. Depth to rock 18 feet. A. T. 617. The bits of rock about well site are blue micaceous flags or sandy shale.

1000 N., 1800 W. Depth to rock 6 feet, total depth 54 feet. A. T. 627. This well is through soapstone 50 feet to sandrock below which was a black soft rock.

1050 N., 50 W. Depth to rock 25 feet, total depth 398 feet. A. T. 639. Mr. Carpenter says that in going down they had to blast through 3 feet of grindstone, then underneath struck dirt and below this there was a crevice in the rock at 30 feet where they left off. Church Bros. report first a hard flint rock for a few feet, a sort of crust then a few feet of grindstone. At 200 feet about 15 feet of sandstone with no crust over it. Under this sandstone the shale was quite black for about 20 feet. The pumping water shows traces of oil. A coarse sandstone at 365 to 375 feet. Cl med., Ca strong, SO_4 strong, Mg Cl_2 probable, white kettle scale, Sp. Wt. 1.006. The well was 340 feet deep, Saturday night, June 7th, and 350 feet deep at noon, June 9th, apparently in a blue shale. Chas. Wright, owner. This well was deepened by Church Brothers. Reactions:

355. Citric acid gives no effervescence, H Cl trace; for SO_4 strong reaction.
365. Citric acid gives a trace, H Cl strong effervescence, for SO_4 only a trace of reaction.
375. In hot citric acid a strong, in cold citric acid moderate affervescence; trace of sulphate.
385. In citric acid traces of effervescence, in H Cl not strong, no sulphates.
389. In hot dil. H Cl traces of effervescence, sulphates present(?).

Section 13.

S. E. quarter of N. E. quarter. A. T. 648.

1360 N., 50 W. SO_4 med., Ca med., Cl med. Depth to rock 32 feet. Total depth 115. D. Ahearn, owner. This well was dug 32 feet in blue clay, probably 40 to 60 feet to rock which is soap rock. Another account says 118 feet in soaprock and sandstone.

30 N., 50 W. SO_4 med., Ca trace, Cl strong, Mg trace. Total depth 137 feet. A. T. 657. T. Walker, owner. The soil is a sandy loam.

50 N., 1210 W. Total depth not yet to bed rock 36 feet.

Section 14.

1500 N., 1050 W. A. T. 612. Depth to rock 7 feet, total depth 92 feet. Robert McAllister, owner. The water was June 26, 1896, 18 feet from top, but is generally about 15 feet from top, and is not enough for stock.

Depth to rock 50 feet, total depth 66 feet. A. T. 622. Ward's well.

Depth to rock 14 feet, total depth 55 feet. Wm. Starbeck, owner.

There are three or four feet of slate and at 14 feet brown rock, and 23 feet of solid rock.

A. T. 622. Total depth 25 to 36 feet. Ed. Gritzner, owner.

Depth to rock 7 feet, total depth 100 feet. Edward Haring, owner.

All the above wells are near by.

Section 15.

250 N., 1000 W. SO_4 trace, Ca low, Cl traces. Depth to rock 33 feet, total depth 47 feet. A. T. 612. This well was dug 23 feet and bored 10 feet, and the rest drilled. Wm. Kennedy, owner.

750 N., 950 W. Depth to rock 7 feet, total depth 83 feet. A. T. 608. This is on the farm next north and east of the last. Shell rock at 7 feet, four feet thick, and then 12 feet through to hard rocks.

About 1000 N., 1000 W. Cl and SO_4 traces, Ca low. Depth to rock 26 feet, total depth 56 feet. A. T. 609. This well was dug 26 feet and drilled 30 feet. Water is scarce on the east side of the road.

Section 19.

50 N., 900 W. Total depth not to rock 37 feet. A. T. 632. This well was dug.

Section 20.

S. W. quarter about 1500 W. Total depth, just to rock, 16 feet. A. T. 602.

740 N., 1000 W. Depth 15 to 20 feet to rock, total depth 42 feet. A. T. 607. Wm. Sawyer, owner. This well is dry in summer. In summer water is taken from spring hole 3 feet deep in shell marl, 100 yards back (W.) of the house in valley of Pinnebog river. SO_4 none, Ca low, Cl trace (in spring water).

1000 N., 1280 W. Total depth 18 feet. A. T. 608. This well is dug in clay.

50 N., 940 W. Depth, not to rock, 40½ feet. A. T. 620. This well is close to margin of valley.

Section 23.

1950 N., 400 W. Depth to rock 50 feet, total depth 66 feet. A. T. 640. SO_4 low, Ca low, Cl low, Mg trace. Ward, owner. Rapson Bros., drillers.

1950 N., 1050 W. A. T. 635. SO_4 low, Ca low, Ca med., Mg tr. J. R. Learned, owner.

1620 N., 950 W. Total depth 14 feet. A. T. 632. SO_4 trace, Ca med., Cl low, white kettle scale. Water is 6 feet below the ground.

900 N., 1000 W. Total depth 30 feet. A. T. 646. SO_4 trace, Ca low, Cl med. L. Scharizer, owner. This well is dug in blue clay.

900 N., 1000 W. A. T. 616. SO_4 trace, Ca low, Cl med. Depth to rock 40 feet, total depth 53 feet. This well passed through 3½ feet of sandstone, then gravel rock, and at very last clear hard rock.

900 N., 2000 W. SO_4 low, Ca low, Cl low. (1) J. Campbell, owner. This is a dug well. (2) SO_4 low, lower than No. 1, Ca low, about equal to No. 1, Ca low, more than in No. 1. This well is about 30 feet deep and probably just to rock.

Section 26.

0 N., 880 W. Total depth 14 feet. A. T. 662. There are other wells in the neighborhood of about the same depth. There is a layer of quicksand about 12 to 14 feet down, below clay.

Section 27.

1950 N., 340 W. Total depth 16 feet. A. T. 632. No. 1 at house.

1950 N., 300 W. SO_4 low, Ca low, Cl low. Depth to rock 8 feet, total depth 22 feet. A. T. 632. This well was dug 18 feet, then drilled 3 or 4 feet in stone. No. 2 is at the barn.

Section 28.

There are dug wells around here 15 to 30 feet deep which do not reach rock.

1900 N., 1240 W. SO_4 trace, Ca low. A. T. 622. This is a flowing well. T. 54° F. June 26, 1896. There are two springs in the place. Total depth 40 feet. This well was hand bored for 40 feet, the auger dropped a little when water was struck.

40 rods N. of the corner, i. e., 250 N., 1980 W. Total depth 50 feet. A. T. 627. This well was dug to sandstone and deepened in 1895. The water was abundant, and the sandstone was of a dark-blue color like grindstone. This answers to the Port Crescent samples.

1000 N., 2000 W. Depth to rock 50 feet, total depth 90 feet. A. T. 639. This well is at the school house. There are other deep wells in the vicinity of the school house.

740 N., 50 W. A. T. 639. H_2, SO_4 none. Ca and Cl low. This well is about the same depth as at school house (about 90 feet to rock).

Section 31.

1950 N., 1200 W. H_2, SO_4 trace, Ca low, Cl low. Depth to rock 30 feet, total depth 96 feet. A. T. 639. James Wheilhan, owner. The rock is probably a sandstone.

1950 N., 1840 W. Depth to rock 30 to 40 feet. A. T. 627. Wm. Whelham, owner.

Section 32. [Pinnebog.]

0 N., 720 W. Total depth about 46 feet. A. T. 627. It is not known whether this well is in rock or not.

0 N., 1280 W. Total depth 32 feet. A. T. 617. This well is not to rock.

0 N., 2000 W. A. T. 614. Smells and tastes of H_2 S. SO_4 trace, Ca low, Cl traces. Total depth 110 feet. James Casey, owner. McLaren, Unionville, driller. The well is said to have flowed at the top of the ground with a strong stream when first dug. H_2 S odor and taste not present until 1896.

Depth to rock 50 feet, total depth 87 feet. Dr. Sellers, owner. A. T. 617. SO_4 trace, Ca low, Cl trace, Fe present, slight H_2 S taste. The rock at top is slate (shale), the rest is sandstone. The water rises to within 6 feet of surface. At one-fourth mile to south rock is 6 feet from surface. O. Erb of Soule, driller.

Section 35.

50 N., 1000 W. Total depth about 52 to 53 feet. A. T. 679. The water is not clear, milky, SO_4 absent, Ca low, Cl trace. Jerome Farwell, owner. This well is said to have struck rock at 9 feet. The water is not clear and is not used. The more it is pumped the more fine sand seems to come up so that the water is almost milky. The sand which settles first is very fine and micaceous. The drillers (McLean and Reed, of Bay City) said bottom of pipe was 6 feet in rock, which is doubtful. Something is wrong with the casing.

There is a well 14 feet in clay 8 feet south of last. SO_4 absent, Ca low, Cl trace.

250 N., 1050 W. Total depth 35 feet. H_2, SO_4 absent, Ca low, Cl trace. The water is milky. The well is "40 rods north of road on W. side." It is said by the drillers to be in rock.

1500 N., 2000 W. SO_4 trace, Ca low, Cl trace. Depth to rock 35 feet, total depth 120 feet. A. T. 661. The water contains much sand of fine grey color. A neighbor said rock was 35 feet from the surface. Thomas Lockman's well.

Section 36.

50 N., 780 W. A. T. 674. The water is abundant. Total depth 14½ feet. The well is dug in clay. Also several others in the same neighborhood with about the same depth and with abundant water.

Dwight Township (T. 18 N., R. 13 E. D.).

Section 1.

1560 N., 0 W. SO_4 traces, Ca and Cl low. Total depth 22 feet. A. T. 637. This well is at the barn and has 14 feet of water.

S. half of S. E. quarter. A. T. 646. (1) Depth to rock 4 feet, total depth 30 feet. This well went dry in the summer of 1895. W. Noble, owner. It was drilled 16 feet in a blue lime rock; in 6 hours it was 26 feet deep. (2) This is a well at the house, it used to flow, but does not flow now. It is 15 feet deep.

50 N., 1160 W. Depth to rock 22 feet, total depth 34 feet. A. T. 652. J. Walsh, owner. Half way back on this farm it is but 5 feet to rock; 11 to 13 feet of grindstone rock.

Section 2.

S. end of E half of N. W. quarter. Total depth 16 feet. Coal is said to occur in this well.

50 N., 1820 W. A. T. about 745. This well is probably 13 to 14 feet deep. Jas. Higgins says that "coal" in a blue-black shale and blue clay occur.

50 N., 1260 W. Water in this well is plenty, SO_4 trace, Ca low, Cl low. L. Total depth 14 to 15 feet. Another well is 18 feet deep.

50 N., 1200 W. Total depth, not to rock, 20 feet at barn.

1840 N., 0 W. Ca trace, Cl trace, SO_4 none. Total depth 90 feet. A. T. 636. This is said to have struck coal "probably through sandstone to a black rock." M. Cary of Badaxe, driller. There was sandstone near the surface, then blue clay 16 or 20 feet, after that blue rock. There is 65 feet of water in the well, and the supply is good.

1420 N., 0 W. Depth 16 feet. A. T. 635. There is no rock, the well is in sand. (2) SO_4 none, Ca trace, Cl none Depth to rock 4 feet. Total depth 10 feet. This well is at the barn in the same locality on property of H. O. Smith, Saginaw.

Section 3.

1900 N., 1420 W. Total depth, not to rock, 7 feet.

50 N., 1740 W. Total depth 10 feet, to rock.

50 N., 1320 W. Total depth not more than 10 feet.

50 N., 800 W. Total depth not more than 77 feet. This well is probably to sandstone. The S. W ¼ of this section is full of boulders and hard heads. From the south quarter post a ridge strikes N. E. on which the sandstone is near or at the surface. It is 4 to 6 feet to rock as shown by the ditches.

1950 N., 700 W. SO_4 trace, Ca low, Cl med. Mr. Sommerville, owner.

Section 5.

50 N., 1100 W. SO_4 and Ca trace, Fe trace, Cl low. Water rose to within 6 feet of the surface. Depth to rock 40 feet, total depth 121 feet. A. T. 628. This well passed through sandstone, then soapstone, then sandstone again. Good water was struck at 45 feet.

Section 6.

E. half of S. E. quarter. Total depth 30 feet, perhaps nearly to bed rock. A. T. 629. This well is through hard blue clay. When the water broke in it came to within 4 feet of the top of the well. C. Culhane, owner. SO_4 low, Ca low, Cl med. Total depth about 60 feet. P. Smeder, driller.

750 N., 1500 W. SO_4 trace, Ca low, Cl trace. Total depth 66 feet. Wm. Davis, driller. This well is now owned by Bleicher.

400 N., 1700 W. SO_4 low, Ca med., Cl low. Depth to rock 9 feet, total depth 10 feet. This well is 8 or 10 inches in rock, a greenish micaceous sandstone.

Section 8.

100 N., 1500 W. SO_4 trace, Ca low, Cl med., Fe trace. Depth to rock 40 feet, total depth 88 feet (other accounts say 100 to 103 feet). A. T. 639. This well passed through soaprock at first, then grindstone and sandstone. Homer Filion, owner; A. Rapson, driller. This is a flowing well. The water rose 2 feet above the surface, which is 10 or 15 feet above the stream valley, but below country level. It has now about one foot head.

1950 N., 1440 W. Depth to rock 42 feet, total depth 66 feet. A. T. 650. SO_4 none, Ca tr., Fe tr., Cl low; rises now to 10 feet below ground. W. McGargle, owner; N. Mosher, driller. There was lots of water at 28 feet before they came to rock.

1950 N., 1200 W. SO_4 trace, Ca low, Fe none, Cl less low than at McGargle's well. Total depth 27 feet. A. T. 652. This well is in a very blue clay, under which is water. There is also a dug well 20 feet, perhaps, to rock.

1660 N., 100 W. Total depth 18 feet. A. T. 630.

50 N., 400 W. Total depth 19 feet. A. T. 660.

Section 9.

50 N., 260 W. Total depth 16 feet. A. T. 662.

50 N., 660 W. and 860 W. A. T. 662.

50 N., 146 W. A. T. 662. The water stands at 4 feet below the surface. Total depth of well 14 feet.

Section 11.

1950 N., 1100 W. Total depth 19 feet. A. T. 645.

1950 N., 820 W. A. T. 650.

1950 N., 780 W. A. T. 650. SO_4 low, Ca med., Cl low.

1950 N., 380 W. A. T. 652. There are three wells on this place 18, 22 and 27 feet deep respectively.

50 N., 200 W. A. T. 672. There are outcrops of sandstone at barn and in the woods.

Section 12.

1950 N., 1360 W. Total depth to rock 18 feet. A. T. 652 feet.

1200 N., 1200 W. Total depth 5, 6 or 7 feet to rock.

50 N., 900 W. A. T. 662. SO_4 none, Ca trace—, Cl low. This well is in blue boulder clay, and not to rock.

50 N., 1420 W. Total depth 8 feet. A. T. 665. The water does not come in fast. This well is through very blue stuff. N. of the house in the hollow it is 22 feet to bed rock.

50 N., 1900 W. Total depth 14 feet. A. T. 672. This well is at the barn.

1700 N., 1900 W. Depth to rock 9 feet, total depth 23 feet. A. T. 646. The water is brackish when pumped. The first well is 30 rods west of road, and passes through some conglomerate; the lower part is very hard. Surface water good. SO_4, Cl and Ca all medium when dipped from top. All strong when pumped. (2) Depth to rock 20 feet, total depth 30 feet. SO_4 and Ca are medium, Cl low. There is not much water in this well in the dry part of summer. It is 5 feet higher than No. 1, and 15 rods east of No. 1. (3) Depth to rock 20 feet, total depth 36 feet. This is at the house. It was drilled 16 feet in rock and it is thought "soapstone" was struck. No water. (4) Across the road is a well 30 to 35 feet deep. (5) Depth to rock 10 feet, total depth 23 feet. The water is brackish. This is in the same vicinity, dug a number of years ago.

Section 13.

1950 N., 1180 W. SO_4 none, Ca trace, Cl low. Depth to rock 7 feet. A. T. 662.

1900 N., 1180 W. Depth to rock 6 feet.

1900 N., 1700 W. Depth to rock 3 feet, total depth 6 feet. A. T. 662. This well passes through not more than 3 feet of shelly grindstone.

1625 N., 1700 W. Total depth 5 feet. A. T. 680. S. E. of the school house is sandstone at the surface.

520 N., 640 W. SO_4 none, Ca trace, Cl trace. Total depth 101½ feet. A. T. 697. Geo. Robinson, owner. There are outcrops of a massive sandstone like that of Port Austin close to the top of the well. At 20 feet there was "vein" of water, and at about 75 feet more water.

100 N., 200 W. Total depth 12 feet. A. T. 692.

Section 14.

1950 N., 200 W. Depth to rock 5 feet. A. T. 680. The water is not plenty in this well, which is at the barn.

1500 N., 200 W. Total depth to rock 9 feet. A. T. 680. This well is at the house near the road. 40 rods south it is only 2 feet to rock, so that they could not drive post holes.

1950 N., 740 W. Total depth, perhaps to rock, 28 feet. A. T. 680.

50 N., 520 W. Total depth, not to rock, 14 feet. A. T. 687. Spalding, owner.

400 N., 50 W. Total depth 20 feet. A. T. 690.

Section 15.

600 N., 100 W. Depth to rock 18 to 20 feet. A. T. 687. At 18 to 20 feet there is a coarse sandrock and the water rises to 4 feet from ground. At 35 feet there was a very hard, very white rock; at 36 feet a sand stream in a seam of the rock.

600 N., 150 W. Depth to rock 22 feet, total depth 25 to 40 feet. A. T. 687. This well was dug 22 feet and drilled 3 feet, and is without much water.

600 N., 50 W. Depth 5½ or 11 feet to water. A. T. 687.

1950 N., 640 W. A. T. 662. This well is through blue sandy clay.

50 N., 1440 W. Total depth about 12 feet. A. T. 698.

Section 16.

1950 N., 780 W. Depth to rock 12 feet, total depth 14 feet. A. T. 662. This well passes through 2 feet of sandrock.

Section 17.

1975 N., 400 W. SO_4 trace, Ca med., Cl med., no iron. Total depth 17 feet. A. T. 658. There was 12 feet of water in a well twenty feet deep, not to rock, near by.

1950 N., 1260 W. Total depth 16 feet. A. T. 654. There is 3 to 4 feet of water in this well.

950 N., 1260 W. Depth to rock 6 to 8 feet.

1140 N., 1950 W. A. T. 650. (1) Depth, just to rock, 32 feet. Whitechurch, driller. (2) Total depth 28 feet.

50 N., 220 W. Total depth 29 feet. A. T. 657.

Section 18.

50 N., 960 W. Total depth 25 feet. (1040 if R. R. is center line.) A. T. 650.

Section 20.

980 N., 220 W. Depth to rock 54 feet, total depth 181 feet. A. T. 652. At about 85 feet the main stream of water came. J. Bleicher, owner. Rapson drilled deeper after Kelly had drilled it to 55 feet with no water. They wanted a flow and therefore had to go deeper than otherwise for water. The rock passed through is bluish. SO_4 trace, Ca low, Cl med. No Fe.

1240 N., 1950 W. A. T. 652. SO_4 trace, Ca low, Cl low. Depth to rock 24 feet, total depth 48 feet. M. Fremont, owner. This well is at the house. Another well at the barn goes 30 feet without striking rock.

Section 21.

1980 N., 1780 W. SO_4 trace, Ca trace, Cl low. This water is unsuitable for washing. Depth to rock 30 or 40 feet. Total depth about 60 feet. A. T. 660. Wooster, owner.

50 N., 840 W. Depth to rock 18 feet, total depth 21 feet. A. T. 672.

Section 22.

1950 N., 1440 W. Depth, not to rock, 16 feet. A. T. 697.

Section 23.

1950 N., 1360 W. Total depth 9 feet. A. T. 688. This well is on the edge of a five-foot gully.

1950 N., 50 W. Total depth 14 feet. A. T. 690. This water is hard.

50 N., 50 W. Depth to rock 10 feet, total depth 10 feet. A. T. 689. This well is to sand rock, and could get no further. There are numerous large blocks of fossiliferous sandstone around here, especially on Sec. 26, which seem to be the outcrops or almost so. In post-holing, and also back on the north end of the lot the rock is shown to be surely in place.

Section 24.

1950 N., 810 W. SO_4 none, Ca trace, Cl trace. Depth to rock 7 feet, total depth 9½ feet. A. T. 690. This well is in soft rock, like sand.

300 N., 100 W. A. T. 677. SO_4 0. Ca trace, Cl trace. Total depth 90 feet. Mr. W. J. Wilson, owner. Tom Rapson, driller. The soil was sandy. At first this well was only 50 feet deep, but the water was not good, and the well was then put down to 90 or 96 feet.

260 N., 50 W. A. T. 672. Total depth 16 feet. This well is through boulder clay.

Section 26.

250 N., 1560 W. SO_4 trace, Ca and Cl low. Total depth 24 feet. A. T. 699. Wm. Robinson, owner. This well is in quicksand 40 rods north of road.

A. T. 689. The sandstone is near the surface at the northeast corner of this section.

Section 27.

0 N., 1640 W. SO_4 tr., Ca low, Cl low. Total depth 38 feet. A. T. 692. This well was dug 16 feet and bored with a two-inch auger to 38 feet. It is not in rock.

Section 28.

1950 N., 50 W. A. T. 646. (1) Total depth 40 to 46 feet. SO_4 trace, Ca low, Cl low. (2) Total depth 24 feet.

1950 N., 1500 W. Depth to rock 12 feet, total depth 15 feet. A. T. 667. This well is through sandy gravel soil; a 15 feet gully occurs just south.

1900 N., 1950 W. Total depth 18 feet. A. T. 662.

Section 30.

820 N., 2000 W. SO_4 low, Ca trace, Cl trace. Total depth 20 feet. A. T. 679. Joseph Thompson, owner. This well is in clay.

1480 N., 2000 W. Total depth 14 feet in clay. A. T. 682.

1040 N., 2000 W. Total depth 12 feet.

Section 31.

1950 N., 780 W. This water is not very hard. Total depth 14 feet. A. T. 682. Frederick Engels, owner. This well is in clay.

Section 32.

2000 N., 1600 W. Total depth 22 feet. A. T. 720. There are four wells here in clay to "gravel."

Section 33.

2000 N., 1860 W. SO_4 trace, Ca and Cl low. Total depth 18 feet. A. T. 698. Jacob Knaski, owner. This is the old saw mill well. There was quicksand at 18 feet, and the well is very full.

Section 34.

2000 N., 1340 W. SO_4 traces, Ca low, Cl low. Total depth 38 feet. A. T. 685. This well is dug 16 feet, and was bored with a two-inch auger to 38 feet. There was no rock.

0 N., 360 W. Total depth 30 feet. A. T. 710. This well is through gravel and clay to bottom of clay where the water broke through.

Section 35.

220 N., 0 W. Total depth 16 feet. A. T. 706. This well is in clay.

640 N., 2000 W. Total depth 22½ feet. A. T. 708. This well is through coarse gravel to clay.

Total depth 22 feet. This well is of the same character as the last and is in the same locality.

Section 36.

2000 N., 1960 W. A. T. 1663. There are two shallow wells here, one 8 feet and the other 12 feet deep in clay. There are no drilled wells in this neighborhood.

Huron Township (T. 18 N., R. 14 E. D. and L.).

According to T. Rapson there is a strip of country about 2 miles wide from Grindstone City to Sand Beach where the water is salty, the section being about as follows:

4 to 5 feet surface, then blue clay.

40 feet rock, a soapstone with a few feet (8-10) of sandstone.

At 100 feet we get salt water.

The wells around here should be 65 to 75 feet deep, if much deeper the water is too salt. In other words, soon after striking the Coldwater shales we get salt water.

Back of Huron City the depth to rock is 25 to 30 feet, total depth 70 feet. The surface wells are 12 to 14 feet deep. The deeper drilled wells are 60 to 70 feet deep. At 65 to 75 feet a sandstone is met, with blue clay above it and soaprock like the bottom of Willow Creek (i. e., shales) below.

Section 2.

150 N., 1400 W. SO_4 tr., Ca low —, Cl low. Depth to rock 3 feet, total depth 10 feet. A. T. 669. Wm. Bruce, owner. It is 3 feet to "shell" rock.

450 N., 320 W. SO_4 trace, Ca low, Cl low. The water is pretty hard. The depth to rock 12 feet, total depth 12 feet. A. T. 659. A. Morrison, owner. This well is at his house. He has a well at the barn 16 feet deep, just to rock, and in 1895 he was short of water.

500 N., 500 W. Total depth, just to rock, 4 feet. A. T. 650. This well is 30 rods back of barn.

Section 4.

1660 N., 640 W. SO_4 low, Ca low, Cl strong, Mg trace. Depth to rock 12 to 13 feet, total depth 18 feet. A. T. 611.

1660 N., 500 W. Total depth 14 feet. A. T. 611.

1600 N., 425 W. SO_4 low, Ca med., Cl med. + Total depth 40 feet. A. T. 636. This well was at Hubbard's barn, now owned by W. L. Phelps.

Section 5.

0 N., 760 W. SO_4 low, Ca low. Depth to rock 25 feet. A. T. 630. In this well there was shell rock 1 foot 10 inches thick and then grindstone. There was a seam containing water between the two.

900 N., 950 W. Total depth 23 feet. A. T. 632. This well was dug by Forbes.

760 N., 1050 W. A. T. 632. (1) Total depth, not to rock, 24 feet. Geo. Wressel, owner, at house. (2) Depth to rock 37 to 39 feet, total depth 63 feet. This well is in sandstone at the barn.

440 N., 1050 W. (1) Depth to rock 11 feet, total depth 15 feet 4 inches. A. T. 637. This well is in rock, a sandstone with a good grit. (2) Depth to rock 5½ feet, total depth 8 feet. A. T. 633. This well is back in the orchard and is lower by four feet.

220 N., 950 W. Depth to rock 5 feet, total depth 8 feet. This well is five feet to rock and goes through 3 feet of grindstone.

Section 6.

1560 N., 2000 W. A. T. 632. SO_4 trace, Ca low, Cl low. There are two wells here, one at the house, and one at the barn. They are 22 feet to rock, total depth 22 feet, and contain 14 feet of water.

260 N., 1000 W. Total depth 35½ feet. A. T. 637. This well was dug 23½ feet and drilled 12 feet. They did not find water. (2) Total depth 11 feet. A. T. 639. (3) Total depth, just to rock, 37 feet. A. T. 639. This well was dug 22 feet and drilled 15 feet, and was probably through grindstone. There was no water at rock.

50 N., 1640 W. A. T. 640. Total depth to rock(?) 22 feet.

Section 7.

1950 N., 400 W. Total depth 28 feet. A. T. 632. Thos. Colander, owner. This well is at the house, and is only to chunks of sandstone.

1900 N., 400 W. Total depth 21 feet. This well is at the barn. There is sandstone in stream 16 feet lower, not far off and blue slate is said to lie over it.

Depth to rock 25 feet or more, total depth 35 feet. A. T. 650. SO_4 tr., Ca low, Cl low, Fe 0. There is plenty of water in this well. McBrine, owner.

1300 N., 1500 W. Depth to rock 40 feet, total depth 60 feet. A. T. 642. From 10 to 40 feet there is blue clay. Chas. Schubel, owner.

About 2000 N., 2000 W. It is 26 feet to rock.

Section 8.

1920 N., 1000 W. Total depth, probably not to rock, 18 feet. A. T. 640.

1920 N., 1000 W. Total depth 13½ feet. A. T. 640.

1120 N., 900 W. Total depth 16 feet. A. T. 657. This well was dry in summer of 1895.

50 N., 1140 W. Total depth probably 14 feet. A. T. 650.

50 N., 1660 W. Total depth 22 to 25 feet. A. T. 657. This well used to be only 18 feet deep, and now goes probably to rock.

50 N., 740 W. SO_4 low, Ca low, Cl trace. Total depth 25 feet. A. T. 640. This well passes through blue grindstone with 1 foot 10 inches of shale at the bottom, with a seam of water between them.

Section 9.

0 N., 1160 W. Depth to rock 4 feet, total depth 5 feet. A. T. 621. This well is in stream valley.

0 N., 1780 W. Total depth, just to rock, 18 feet. A. T. 643.

Section 10.

900 N., 50 W. Ca tr., SO_4 0, Cl 0. Depth to rock 10 feet, total depth 15 feet. A. T. 663. This well was incomplete, and passed through soft slabby sandstone that could be handled with pick and shovel.

1240 N., 50 W. Total depth 9 or 10 feet, not to rock. A. T. 642.

1640 N., 50 W. Total depth 8 feet. A. T. 642.

Section 11.

1700 N., 1100 W. The water is harder than in the well north. (1) Total depth 16 feet at the house. SO_4?, Ca med., Cl low. (2) Depth to rock 4 feet, total depth 87 feet at the barn.

4 feet surface before rock.

12 feet dug in sandstone (Lower Marshall sandstone?).

87 feet drilled, but not enough water came to drill with (Coldwater shale).

There was no gravel in this well.

1700 N., 950 W. Depth to rock 4 to 6 feet, total depth 22 feet. SO_4 none, Ca tr., Cl tr., soft water. This well is right on front of the terrace close to a steep descent.

465 N., 50 W. This well is in rock, total depth 6 feet.

300 N., 1950 W. Depth to rock 8 feet, total depth 18 feet.

Section 12.

460 N., 1950 W. Total depth 13 feet. A. T. 632. This is a drilled well for 12 feet. The water comes slowly (probably in the shale).

Section 13.

750 N., 1950 W. Depth to rock 15 to 16 feet. A. T. 652. The last ten feet of this well was dynamited through fine grained sandstone (grindstone with streaks of blue shale), not very fossiliferous.

50 N., 700 W. Depth to rock 6 feet, total depth 18 feet. A. T. 652. A. Brinning, owner.

1900 N., 1200 W. A. T. 627. (1) This well is said to be in rock only 8 feet, total depth 32 feet, but the bluff nearby shows arenaceous shale close to the surface. (2) Total depth 22 feet. (3) Total depth 14 feet. The wells around here are never dry, but do not yield much water.

Section 14.

50 N., 200 W. Depth to rock 10½ feet, total depth 12 feet. A. T. 645.

100 N., 360 W. Total depth 4 feet. A. T. 645. This is merely a hole, and has poor water.

Section 15.

1900 N., 1600 W. SO_4 0, Ca tr., Cl low. Depth to rock 4 feet, total depth 16 feet. A. T. 676.

1900 N., 1120 W. Depth to rock 8 feet, total depth 15 feet. A. T. 683. This well has plenty of water. This well is in grindstone rock. Rock has been found in post holes between the two wells just mentioned.

Section 16.

2000 N., about 475 W. Depth to rock 16 feet.

180 N., 1050 W. Depth to rock 3.5 feet, total depth 15½ feet. A. T. 645. This well passes through 5 feet of rock and 7 feet of clay, then grindstone and water.

Depth to rock 7 feet. This is north of the last mentioned well and found water.

1500 N., 600 W. Depth to rock 2½ feet, total depth 12½ feet. A. T. 640. This well passed through 10 feet of sandstone, then grindstone, and is at the school house.

1900 N., 440 W. Depth to rock 16 feet. A. T. 649.

Section 18.

1900 N., 1100 W. Depth to rock 25 to 26 feet, total depth 30 to 36 feet. This well is in rock. Water around here is generally found at 8 to 10 feet in gravel.

980 N., 1000 W. SO_4 strong, Cl strong, Ca med. Depth to rock 52 feet, total depth 87 feet. A. T. 666. Evan Wade, owner. This well has been also reported to be 40 feet to rock and 60 to 80 feet deep. It goes through 15 feet of grindstone, then through soap rock or clay into sandstone again. In the bottom of the creek there is blue clay.

1600 N., 950 W. Depth to rock 52 or 53 feet, total depth 52 or 53 feet. A. T. 627. M. McDonald, owner. This well was dug 20 feet, and bored 32 feet.

SO_4 low, Ca med., Cl med. Total depth 7 feet. A. T. 627. This is a dug well at the barn.

1280 N., 1950 W. Total depth, not to rock, 19½ feet. This well is in clay.

Section 19.

1950 N., 1140 W. Depth to rock 22 to 23 feet. A. T. 653. This well is in clay to quicksand.

Section 21.

300 N., 950 W. Total depth 13 feet. A. T. 670. This well is in clay.

2000 N., 950 W. Depth to rock 10 feet, total depth 11½ feet. A. T. 642. There is 2 feet of grindstone in this well, then 1 foot of blue clay.

Depth to rock 11 feet, total depth 14 feet. A. T. about 642.

2000 N., 1900 W. Depth to rock 10 feet, total depth 14 feet. A. T. 652. This well is in sandstone. The rock is said to be 9 to 11 feet from the surface and makes a layer of sandstone 2 feet thick, then comes 10 feet of blue clay, then sandrock again. The clay probably represents shale.

Section 24.

1800 N., 1800 W. Depth to rock 10 feet, total depth 12 feet. A. T. 650. Tischendorf, owner.

1900 N., 1160 W. Depth to rock 6 feet, total depth 22 feet. A. T. 650. This well was drilled and blasted. A. F. Banker, owner.

1900 N. Total depth 14 feet. A. T. 650.

Section 28.

50 N., 820 W. A. T. 687. SO_4 tr., Ca tr., Cl low. Depth to rock 13 feet, total depth 16 feet. This well is at the house east of road, and passes into grindstone rock. There is a well 13 feet deep, just to rock, east of this one.

Section 29.

1750 N., 1700 W. 40 rods E. and 40 rods S. of N. E. corner of Sec. 29. H_2SO_4 trace, Ca trace, Cl low. Depth to rock 38 feet, total depth 52 feet. A. T. 692. Thomas King, owner; T. Rapson, driller. The rock in this well is probably grindstone for 12 feet, then soapstone.

1000 N., 1000 W. Depth to rock 28 feet, total depth 28 feet. A. T. 644. Mr. Gaine, owner. This well is at the edge of the stream ½ mile N. and W. of S. E. cor. of Sec. 30 (?).

Section 30.

50 N., 1720 W. Depth 16 feet. A. T. 691. This well is in gravel and clay.

50 N., 50 W. Total depth 26 feet. A. T. 684.

Section 31.

1950 N., 160 W. Total depth 10 feet. A. T. 684. In clay. There is 4 feet of water in this well.

Section 33.

1900 N., 700 W. Total depth, just to rock, 13 feet. A. T. 685. This well is to grindstone.

About 1500 N., about 1000 W. Depth to rock 13 or 14 feet.

Section 34.

2000 N., 500 W. Depth 10 to 20 feet. A. T. 691. This is the average depth for wells around here to grindstone rock.

0 N., 480 W. Depth to rock 7 feet. A. T. 704.

Gore Township (T. 18 N., R. 15 E. L.).

In a strip of country about 2 miles wide, water is salty at about 100 feet, for example, Weiss's well.

Section 18.

0 N., 1900 W.. A. T. 627. (1) W. H. Cole, owner, at house. Total depth 26 feet. (2) Water in a blue stony gravelly clay (till), cold but not abundant.

Section 30.

Cl med. Depth to rock 28 feet. A. T. 681. This well was bored but the tools stuck. Chas. Gettz, owner.

Section 32.

100 N., 1600 W. Depth to rock 30 feet, total depth 154 feet. A. T. 659. Cl strong, salty taste. F. Weiss, owner. At about 35 feet soapstone, a little water, no more was found in going deeper.

Section 33.

900 N., 1300 W. Wm. Schlaach, owner. A. T. 600. This well is said to vary with the wind, rising when the wind is off the lake. The well is close to the lake.

Port Austin Township (T. 19 N., R. 12 E.).

Section 25.

E. ½ of S. E. ¼. Total depth about 1200 feet. A. T. 592. This is the well reported by Rominger and Garrigues had drillings of it. See Vol. V, Pt. II, p. 75-76. Summary of record: 1-336 feet sandstones and conglomerates of the Lower Marshall, fresh water; 336-1120, blue shale; 1120-1160, red shale (Berea shale) at bottom; 1160-1225, sandstone, brine (the Berea Grit).

Section 36.

Depth to rock about 16 feet, total depth 40 feet. A. T. 616. SO_2 trace, Ca med., Cl low, red matter. This well went through 10 feet of sand, then red clay to rock.

Depth to rock 6 feet, total depth 80 feet. A. T. 610. 50 steps farther on. SO_4 trace, Ca low, Cl trace. Some parts of this well are blue stone, and from 78-80 is hard blue rock.

1000 N., 50 W. Depth to rock 2 feet, total depth 40 feet. A. T. 632. SO_4 0, Ca trace, Cl trace. Water comes in at about 5 feet. J. R. Learned, owner. There is a well near by about 7 feet deep.

T. 19 N., R. 13 E.

Section 23.

The section exposed June 24, 1896, showed 9 inches arenaceous shale, 3 inches conglomerate, 12 feet grindstone. There was a well according to Supt. Wallace,

800 N., 1000 W. A. T. 592, which shows 0-25 feet, grindstone, then soaprock, etc., at 80 feet brine in 3 feet of sandstone, at 95 feet soap rock. It is probably the same well as the following; also said to be at Eagle Bay: 0-24, sandstone; 24 to 54 soaprock, 54 to 78 feet sandstone, and the rest shale. The sandstone has conglomerate streaks, bits of coal and fish teeth. A well, 100 yards away is said to have shown coal, cf. Geol. Surv. of Mich., III, p. 71. Winchell also reports a pocket of coal as having been uncovered in grindstone quarrying. At the grindstone quarries, "there are 30 feet of soapstone, 24 feet of sandstone, and the rest is shale." 100 yards away there was another well with core.

340 N., 950 W. Depth to rock 5 feet, total depth 10 feet. A. T. 596. This is on top of a slight rise and goes into fine grained rock.

Section 25. Grindstone City.

1600 N., 600 W. A. T. 592. (1) This is at the present meat market, close to the station. See Vol. V. p. 62. The Berea sandstone is said to occur at 1010 to 1080 feet depth.

(2) In the present grindstone mill about 200 feet east, about as deep.

1600 N., 525 W. A. T. 592. In September, 1897. Church Brothers and Company put down, close to this well in the Cleveland Stone Company's quarry, a well for water. In the first ten feet some water was met in some salty shales which was cased off. Cf. E. Wade's well on Sec. 18, T. 18 N., R. 14 E. Then they went (360 + 75) 435 feet without getting water, i. e., in the Coldwater shales all the way.

1250 N., 200 W. Total depth 19 feet. A. T. 602. It is five feet to loose rock in this well, and 8 feet through grindstone to water, and then 7 feet of soaprock.

50 N., 1460 W. A. T. 612. At school house. This water is yellow. Pumping two pails exhausts the well. SO_4 0, Ca tr., Cl low. Drilled well.

1950 N., 120 W. 7 feet to rock. A. T. 599. The record at the quarry near by is as follows: 1 foot dirt, 1 foot loose stuff, 10 feet quarry, 30 feet from bottom of quarry to soaprock. There is no water in this well.

Section 26.

50 N., 1820 W. A. T. 636. SO_4 low (like R. Lundy on Sec. 34, T. 19 N., R. 13 E.), Cl med., Ca low, Mg trace. This is a drilled well.

50 N., 1280 W. Depth to rock 5 feet, total depth 112 feet. A. T. 632. SO_4 tr., Ca (lowest of the wells anywhere near) tr., Cl tr., Mg. tr. Wm. Nash, owner. This well passed through 5 feet of surface, 10 to 12 feet of sandstone, 20 feet of grindstone, 5 to 6 feet of soaprock, then grindstone and then soaprock, mainly, with hard veins and black stuff at bottom. There is black oil on the water. (The hard veins are probably nodules of carbonates or pyrite.)

50 N., 740 W. Depth to rock 4 feet, total depth 10 feet. A. T. 640. This well passes through 4 feet of drift, 6 feet of sandstone, then blue shale. In some places it is but 18 inches to rock on this farm.

1060 N., 160 W. SO_4 low, Ca low, Cl low. Total depth 20 feet. A. T. 603. Wm. Jackson, owner.

1950 N., 1900 W. Depth to rock 18.5 feet. Total depth 19 feet. A. T. 632. The water rose at first to 8 feet from top, now it is 14 feet from the surface, Ca low, SO_4 low, Cl med.

Section 27.

50 N., 1900 W. Total depth 10 feet. A. T. 622. There are four wells around here and they were dry in the summer of 1895. SO_4 low, Ca med., Cl strong, Mg low. Mrs. Kramer, owner. Some people like the salt taste of this well better.

50 N., 1760 W. SO_4 very low, Cl med., Mg tr., Ca med. (all less than in the ten-foot wells. Total depth 17 feet. A. T. 622. This well was drilled by Tom Rapson.

50 N., 800 W. SO_4 trace +, Ca low, Cl med., Mg tr. Brownish white scale of

carbonates on the kettle, pretty hard. Depth to rock 12 feet, total depth 90 feet. A. T. 610. Ed. Meagher, owner. This well passed through 12 feet of surface, 40 feet of sandstone with 2 to 3 feet of gravel bed (conglomerate) at bottom, 41 feet of soapstone. There was no gain in water supply in this last.

1080 N., 1900 W. SO_4 tr., Ca low. Cl low. Depth to rock 16 feet. A. T. 612.

1950 N., 1320 W. Total depth 8 feet. A. T. 612. This well is 2 feet in rock.

1950 N., 180 W. Cl low, SO_4 low, Ca low. Total depth 14 feet. A. T. 642. J. Hall, owner. This well is at the house and goes only into loose broken rock.

1950 N., 280 W. Cl low, SO_4 low, Ca low. Ca and SO_4 less than at house. Depth to rock 8 feet, total depth 10 feet. A. T. 642. This well is at the barn.

Section 28.

A. T. 610. Depth to rock 18 feet, total depth 75 feet.

Section 29.

(1050 feet) 400 N., 1990 W., A. T. 596. Railroad well. This is hard water. The record is by J. Pearson, Dec., 1895. Total depth 102 feet, soil, sand 5 feet, 95 feet rock, clay and water under.

(3040 feet N., 80 feet E.) 1150 paces N., 1940 paces W. A. T. 587. Total depth 1200 feet. SO_4 strong, Cl med., more Ca than lake water, Fe not enough to give yellow precipitate. Carrington's salt works has an abandoned flowing well.

(2) 1000 N., 225 W. Depth 1198 feet. A. T. 590. Ayres' well is similar, "second salt well in Michigan." Cf. Record given by Wright, Geol. Surv. Mich., V, p. 76.

1-275 feet sandy shale.
275-1100 feet blue and red shales.
1100-1200 feet porous sandstone.
The analysis of the brine is given in a previous section.

Section 30. Port Austin.

The wells around Port Austin are 60 to 100 feet deep and the rock is close to the surface. Some of the wells are flowing.

A. T. about 600. 13½ feet to rock, total depth 14 feet. Carpenter, owner. This well is 3 feet in gravel and 6 inches in rock. There are several wells about 14 feet deep, all similar, owner by Addison, Williams, Cartwright, and Latham.

450 N., 1200 W. A. T. 610. Depth to rock 16 feet, total depth 60 feet. (At the Methodist church the rock surface leaves the sand and begins to get clay on top.) It is about 16 feet to rock.

A. T. 802. Depth to rock 4 feet, total depth 75 feet. Ayres, owner. The record is from memory, white sandrock, slate rock with a darker black scum to water. Quite a streak to soaprock, grindstone, coarse gravel and sandrock.

400 N., 1000 W. SO_4 low, Ca low, Cl strong. Total depth 104 feet. A. T. 607. J. Buttars, owner. The water was cut off at 75 feet.

800 N., 450 W. Depth to rock 15½ feet, total depth 112 feet. A. T. 595. The water rose to 5 feet below the surface and there was plenty of it. Cl low, Ca low, SO_4 low, Mg, CO_2 present. The water left a red tea kettle scale. 96½ feet of the rock was blue stone, etc. Mr. Lundy, owner, on Spring street.

650 feet N., 900 feet W. 245 paces N., 337 W. Cl low, SO_4 low, Ca low. Depth to rock 12 feet, total depth 60 feet. A. T. 599. J. R. Learned, owner.

225 N., 150 W. Cl strong, SO_4 med., Cl med. Total depth 165 feet. A. T. 596. This well is at the barn and used to flow more than at the house.

300 N., 75 W. Depth to rock 10 feet, total depth 10 feet. A. T. 592. This well is at the creamery. There is a well 17 feet deep at the planing mill.

750 N., 710 W. Lot 20 of original plat. Total depth 90 feet. A. T. 590.

A water from Port Austin has Sp. Wt. 1.004. Cf. Learned's well. In a well ½ mile from shore, the water is said to be roily when the lake is stormy.

Section 31.

920 N., 500 W. A. T. 610. Total depth 17 feet. There is no bed rock in this well, but there is 10 feet of water.

160 N., about 500 W. A. T. 610. Total depth 24 feet. This well is through clay to sand and has 12 feet of water.

Section 32.

810 N., 50 W. Total depth, not to bed rock, 16 feet. A. T. 612.

1950 N., 1240 W. A. T. 612. Blue sand and clay were thrown out of this well.

Section 33.

1956 N., 300 W. Total depth 100 or 110 feet. SO_4 low, Ca low, Cl med., Mg low. The water is too salt. The well is at J. Ryan's house.

1950 N., 1840 W. Mg?, Ca low, Cl med., SO_4 low, Mg SO_4 rather marked. Depth to rock 17 feet, total depth 22 feet. A. T. 609. S. J. Murdens, owner.

1950 N., 1260 W. Depth to rock 12 feet, total depth 12 feet. A. T. 602. SO_4 low, Cl med., but less than at Murden's, not half as much Mg SO_4, but more Ca. This well was dug to rock. This is a flat ground moraine country.

1950 N., 860 W. Total depth, just to rock, 16 feet. A. T. 610. The well is sometimes dry. SO_4 low, Ca low, Cl med. +, Mg low.

Section 34.

E. half of N. W. quarter, 1950 N., 700 W. There is plenty of water in this well. SO_4 low, but more than in last well on Sec. 27-19-13. Depth to rock 21 or 18 feet, total depth 40 or 42 feet.

100 N., 100 W. Total depth 16 feet, not to rock. A. T. 627.

50 N., 1260 W. Total depth 22 feet. This well once went dry.

50 N., 1960 W. SO_4 low, Ca low, Cl med. Total depth 18 feet (just to rock?).

640 N., 107 W. Total depth 22 feet. V. Kula, owner (nearly to rock?).

1950 N., 700 W. A. T. 620. SO_4 low. Depth to rock near 21 feet, total depth 42 feet. R. Lundy, owner.

50 N., 740 W. A. T. 622. This is a shallow well.

50 N., 860 W. This is another shallow well.

50 N., 1260 W. A. T. 622. Total depth 22 feet. This well once went dry.

50 N., 1960 W. SO_4 low, Ca low, Cl med. Depth to rock 18 feet, total depth 18 feet. A. T. 617. This well is through clay.

Section 35.

1950 N., 1640 W. Depth to rock 8 feet (? a boulder), total depth 10 feet. A. T. 625. Wm. Underwood, owner. The well is about 6 feet above stream, which does not expose rock, SO_4 low, Ca low, Cl med., Mg low.

1950 N., 740 W. Ca tr, SO_4 tr. Total depth 18 to 20 feet. A. T. 640. This well is mostly through shale.

100 N., 1900 W. Total depth 18 feet. A. T. 627.

Section 36.

1950 N., 680 W. SO_4 tr, Ca low, Cl low. Depth to rock 16 feet, total depth 23 feet. A. T. 622. W. J. Harrington, owner. Drilled by W. Smith.

50 N., 1340 W. A. T. 629. Depth to rock 20 feet, total depth 23 feet.

Huron Township (T. 19 N., R. 14 E.).

Section 31.

1900 N., 900 W. SO_4 tr., Ca low, Cl med. The water rises to about 17 feet. Depth to rock, just 16 feet., total depth 100 feet. A. T. 616. Record as follows: 2 feet of soil, 14 feet of hardpan, 12 feet grindstone and the rest soap rock with seams of grit. F. Kinch, owner. There are also two other wells just to the rock 14 and 16 feet deep.

920 N., 50 W. Total depth, not to rock, 17 feet. A. T. 603. This well contains 10 feet of water.

160 N., 50 W. Total depth 24 feet. A. T. 618. This well is down in clay to sand and contains 12 feet of water.

1160 N., 50 W. Depth to rock 35 feet, total depth 40 feet. A. T. 607. 5 feet of this well is drilled in rock.

Section 31.

840 N., 1950 W. Total depth 13 feet. A. T. 624. This well is in clay.

Section 32.

500 N., 100 W. A. T. 607. This is a shallow well in gravel, practically a spring.

100 N., 500 W. A. T. 612. Total depth 40 feet.

A. T. 606. The New River salt well, vol. V, pp. 72-5.

1-15 feet grindstone.

15-45 feet blue shale.

At 90 feet salt brine, probably from the Point aux Barques lighthouse conglomerate.

45-800 feet alternate shale and sandrock.

800-900 feet rotten, bad smelling soft rock, including the Berea shale.

900-1000 feet porous coarse grained white sand rock, brine 85°. This is the Berea Grit.

1000-1029 feet blue shale. Bedford shales.

S. W. quarter of S. W. quarter. SO_4 low, Ca low, Cl med. Depth to rock 22 feet, total depth 39 feet. A. T. 604. Moses Thompson, owner. Through 17 feet of blue arenaceous shale. (2) Depth to rock 19 feet, total depth 21 feet. A. T. 607. This well is 2 feet in rock, 4 or 5 feet of sand came, then clay, hardpan and gravel. Dixon is said to have a well over 100 feet deep.

CHAPTER VII.

ECONOMIC GEOLOGY, OR RAW MATERIALS OF THE COUNTY.

§ 1. Introduction.

There are many things classed as raw materials which are not so. Pig iron is classed as raw material by the user of it, but it is the finished product of the furnace man. Wool is the raw material of woolen manufacturer, but the product of the farmer. The only real raw materials are those to which man has contributed nothing of value by his labor. They are the natural resources of the country, and their value cannot be separated from the value of the land which controls their production. We do not, however, intend in this chapter to be rigidly academic in our classification, but intend to supplement Chapter V by trespassing somewhat on the domain of the Commissioner of Mineral Statistics and giving some account of the principal industries that are or may be developed in the county, in their immediate geological bearings. As the great foundation industry is farming, it is fit that we should begin with some notes on the soils.

The map of the Surface Geology, which is given on Plate VIII, may also be taken, as is obvious from the explanation, as in some degree a map of the soils also.

§ 2. Soils.

It is impossible to make a soil map of a county which shall be really accurate and, even then it would be so only for a short time, without going into a detail expensive beyond reason. Moreover, any wise man will look at a farm for himself before buying it. In a previous chapter (Chapter III, § 6, and Pl. VIII), in describing the physiographic districts we have suggested the general distribution of soils. Some hints may be of practical advantage, nevertheless. If an early map of the county such as Farmer's be consulted, it will be found that a large part of the latter was described as swamp, and beaver dams are sometimes noted along the streams (Land Office maps and early railroad surveys). As the land is cleared and drained, the swamp would disappear but the vegetable mold or muck e. g., southwest of Caseville and Badaxe would remain as the base of a fertile black soil if not removed. The great fires which swept the county have, however, largely burnt off this vegetable mold and all the native seeds with it, as noted in Chapter X, on the flora. Not only that, but even now it is quite common, as I have observed for example in Fairhaven and Winsor townships, in clearing up low land in dry summers to burn off all the old vegetable mold. Something of possible fertility is thereby always lost, and when as sometimes happens, especially in the western shore district, below the mold there is nothing but clean sand, the lasting fertility of the land is seriously injured by this carelessness. However, it sometimes happens that these swamps were once shallow ponds, like the cranberry bog back of Hat Point and on Charity Island, and the swamps south of Badaxe and north of Ruth. In that case under the muck are likely to come beds of shell marl which are extremely fertile. Such marly drained lake bottoms make the most fertile of land, and a number of ponds offer tempting opportunities for such drainage. Bear Lake near Port Austin has thus been drained quite recently, and the lake bottom is now said to yield two and a half tons of timothy per acre. Consequently on the map Plate VIII of the surface Geology I might easily have indicated the swamps as more extensive if I included all that land which had had a peaty black soil covering at one time. I have tried rather to indicate the more characteristically swampy parts, where it still exists and has considerable depth. On the other hand the map will soon be inaccurate the other way as the peat is burnt off.

The main soil of the county is clay, clay loam, or gravelly clay, and there are usually enough limestone pebbles scattered through it to keep it well supplied with lime and prevent souring. What Davis says about the greater amount of lime in the surface clay wells is significant. At the same time there is enough mica and feldspar to keep it well supplied with potash, so that its fertility will probably be quite lasting. In the area enclosed within the outcrop of the Michigan series where the water is sulphated, land plaster will not be necessary. The fertilizer most needed would seem to be phosphates like guano.

A word about the boulders and stones strewn over the surface in belts very often roughly parallel to the shores of the county. Outside the district of glacial deposits in the boulder benches proper these thickly scattered boulders are likely to prove superficial, and once picked up, the soil beneath may prove comparatively free from stone. In the hill district, however, the case is different, and some of the moraine hills are likely to yield their crop of "hardheads" quite steadily. Sand dunes are indicated on the map, Plate VIII, by broken contours, as well as by the yellow dots assigned to sand, and I regret that the registration is not always all that it should be.

The least fertile soil in the county is that of the dune sands of the western shore. Yet it must be remembered that just such a soil in New Jersey has proven excellent material to hold plants upright while they were fed by fertilizers, and more money has been made out of small farms and small fruit in that region than can easily be computed. The sand region of Huron county is much resorted to about blueberry time, and when Saginaw and Bay City have a million population these sand dunes may be full of truck farmers. But successful farming on such a soil means fertilizers in large and frequent doses,—intensive cultivation. In the meantime these sands are not devoid of value for other purposes. Where the sand is thin, and this is frequently the case especially in the regions indicated as sandy above the Algonquin, 610 feet, level the soil with a light six inches of sand above and clay below is most excellent for farming, and more easily worked than the stiffer clays.

§ 3. Sand.

Frequently dune sand is too round for building purposes, but certain parts of the sands of the district we have just mentioned are tolerably sharp. This is probably because they have been derived with comparatively little handling from the sandstones of the Marshall, which have angular grains of sand. The only points from which I know of shipments are from Port Austin, shipped by E. M. Carrington, and from Port Crescent, shipped by Miss E. Haskell. Sands equally good probably occur at intervals from New River to Oak Point. This sand is largely shipped to the Lake Superior copper regions where it is used as a lining for the bottoms of furnaces employed in copper smelting and for repairs; it requires for this work a moderately clean and sharp sand of medium fineness. It should be nearly pure silica, but requires a trace of iron or some fluxing material sufficient to cement the sand in a mass under a very high heat, but in no case melt it, or soften it so that any part of it will slag. It requires a sharp sand on the same principle that sharp sand will make the strongest mortar.

"The lake smelters have used 500 to 700 tons of this sand for a term of years, but are not likely to use so much in the future as there is a Pennsylvania sand that is more economical for the surface bottoms. The Port Austin sand will continue to be used for repairs."*

The sand from Port Austin and Port Crescent is "of the same quality, so far as we can see. The sand we get is shore sand washed up by the waves during heavy storms. That portion of the sand from any considerable distance from the shore is of no value to us*

There has been an analysis of the sand made but we have not been able to get it, and it has not been deemed necessary to make another as we are assured by the users, that next to its being nearly pure silica, the essential is its angularity. We do not know why it must be close to the waves unless that the farther it gets from the waves the rounder it becomes by rebounding; possibly the lime that exists in the water of the lake and would be deposited on evaporation furnishes just that minute amount of flux necessary.

An examination of the sand shows that it is mainly of quartz grains though little garnets and bits of feldspar, etc., occur. There is much less iron than many sands have. The form of the grains is sharp and much more irregular than in many sands, for example the Sylvania sand and similar beds. It is in other words nearly the sharp grits of the Marshall disintegrated by solution of the sideritic cement and not essentially rounded in rehandling. Besides being shipped to Hancock and Dollar Bay in the copper country it is also shipped to Toledo and Detroit. The price realized was in 1896 $1.00 a ton loaded or 40 cents unloaded. In 1897, at least 600 tons were shipped to Lake Superior.

From what has been said it is obvious that this sand would make an excellent mortar or all round building sand.

§ 4. Sandstones and grindstones.

The same angularity which we have just noticed in the sand is also to be noted as an important fact in the grains of the grindstones of the Marshall group. Like the Berea they may properly be called "grits." The principal use of the sandstone has been for whetstones and building, and the former use is so much the more important that we treat it first.

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*(Letters of J. R. Cooper, Supt. Detroit and L. S. Smelting Works.)

(a) The grindstone quarries.

The grindstone quarry industry was one of the earliest developed in the county. It was started by A. C. Peer in 1850. It has been mainly carried on by two firms. Mr. Peer's firm became Johnson Peer & Wallace, and later the Huron Grindstone Company with L. R. Wallace as superintendent. The other company is the Cleveland Stone Company with Geo. S. Robertson as Superintendent. In 1896 the Cleveland Stone Company had its main quarry on Sec. 24 and 25 and the Huron Grindstone Company on Sec. 23, T. 19 N., R. 13 E., but the coast all along to Sec. 30, where the quarry was in Winchell's time, has been worked over, the waste stone being thrown into the old workings, which have in some cases then been reoccupied by buildings. There is quite an area yet to be worked along shore, and apparently along Willow Creek the same or similar beds can be found. This stone has already been partly described in a previous chapter. The thickness of the most uniform bed is about 15 feet, and often the cross-bedding is entirely obscure, so that the rock seems perfectly homogeneous. This is the most valuable part. At other times the cross-bedding interferes with the production of large stones. Stones weighing up to 7,800 pounds, or say three tons, have been secured. I noticed one that had been abandoned for its original purpose and turned into a fine drinking trough, about 7 feet across. The face of the quarry is liable to check—crack—under the action of frost and therefore it is the custom to protect the face of the quarry with sawdust in winter. The best stone is turned into grindstones of various sizes, which are sold all over this country and even sent abroad, and are especially valuable for not glazing. This is due to the fact that the sharp angular cutting quartz grit is embedded in a softer cement of mica, siderite, clay, etc., which wears away just fast enough not to allow the rock to polish. It is the combination of evenness of grain, sharpness of grit, and cementing material just soft enough which gives this stone its peculiar value.

The smaller material is made into scythestones (Sp. 19017), and the waste material remaining is used for building and underpinning. For this purpose it is not so very well adapted, owing to its porosity, and tendency to check already mentioned. It is a much better grindstone than building stone. However, it has a pleasing color, blue to bluish grey, with a greenish cast, and has been more or less worked up into caps and sills, etc. A number of underpinnings and one or two houses may be noticed in Badaxe made of this stone. The Sebewaing Marble Works also use it for sills to marble gravestones. Its fine grain and free working make it very amenable to the mason's chisel.

Underneath the sandstone layers come more argillaceous ones variously called blue shale, soaprock, etc., which are quite firm and being presumably less porous would, I should think, be even better for sills and underpinning than the main quarry. The underpinning of the Dunster block in Badaxe is, I understand, of this bed.

The following figures for which we thank Mr. H. W. Caldwell give the product of the Cleveland Stone Co. for 1898 and 1899:

From Grindstone City.		From Port Austin.		Description.
1898.	1899.	1898	1899.	
1,626 cu. ft.	681 cu. ft.			Block stone.
2,990 cu. ft.	2,288 cu. ft.			Sawed flagging.
3,307 tons.	3,733 tons.			Perch stone.
3,606 tons.	3,855 tons.	1,232 tons.	1,576 tons.	Loose grindstone.
6,320 pcs.	11,292 pcs.	5,292 pcs.	8,532 pcs.	Mounted "
3,957½ gross.	4,259 gross.	1,316 gross.	1,951 gross.	Scythe stones.

(b). The Babbitt sandstone quarry.

This quarry was opened in the Napoleon sandstone near Rush Lake, on Lot 3 of Sec. 15, T. 18 N., R. 11 E. Mr. B. Smalley of Caseville was also interested in this quarry. An example of sandstone may be seen in the monument to the memory of his wife, Nancy M. Smalley, in the cemetery near Caseville, which was erected in 1887. Buckley in his report on the Building and Ornamental stones of Wisconsin* says that coarse pores are not as deleterious as fine pores. So here in spite of the high porosity of the stone (Sp. 19161, Table II, p. 90) the monument seems to have held its lettering well. The sandstone is rather coarse (grains about 1 mm. or one twenty-fifth of an inch in diameter), nearly white with a buff or olive hue showing minute brown points, which might on deeper quarrying prove to be weathered pyrite. It is at present owned by Mrs. J. W. Babbitt, of Ypsilanti, and has not been operated lately. Some of this sandstone has been shipped to Detroit, and may be seen in a house there.

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*Bull. Wis. Survey, No. IV, 1898, p. 21, etc.

§ 5. Shales and clays.

The use of an argillaceous bed next to the grindstone for underpinning in the Dunster block opposite the Irwin House in Badaxe I have just mentioned, but in general the shales and clays are not firmly enough consolidated to make building material without farther treatment. In other words they are suited better for brick. Most of the clay of Huron county that I have examined have occasional little pebbles of limestone that cause a certain amount of loss in making brick, as in the burning process such pebbles slake more or less, and the escaping gas "bursts the brick, and there is a spot of slaked lime left as a weak spot in the brick." Such waste brick, however, make excellent material for road mending, and should be widely used.

The clay at Sebewaing is washed, as is more fully described below and in Vol. VIII, Part I. The clays are probably, like almost all the surface clays of the state, calcareous, containing much carbonate of lime in a finely divided state. This tends to produce white brick as it neutralizes the iron but such clays are readily fusible and cannot be burned hard without melting.

The shales, especially some of the beds of the Michigan series, seem quite plastic and pure, but it is dangerous to judge from churn drill samples. They are exposed extensively only by the coal working around Sebewaing, in connection with the grindstones as already described, thence south to the Point aux Barques lighthouse, and on Section 32 White Rock. Here they are well exposed in the bluffs for over a quarter of a mile, and also in a bed of a creek up to the road. This last exposure appears to be a very clean shale, and well suited for making high grade clay products. It is similar in character to the shales used for the manufacture of Portland cement in Branch county and should the marl beds back of the Forest Beaches or in Sanilac county prove to be extensive, it might well assist in the establishment of a cement industry. A description of the shales near White Rock and their tests, and analysis will be found in Part I of Vol. VIII by Prof. Ries, as follows:

White Rock.

Excellent exposures of Coldwater shale occur along the shore of Lake Huron between White Rock and Forestville (Part III), but they have not thus far been utilized.

The shale forms a line of cliffs, and when fresh appears brittle and gritty; in places, however, it has mellowed down to a tough clay.

The rock is a thinly laminated shale (179), which contains much sand of a very fine nature, and slakes slowly along the layers. It worked up with 19% of water to a mass of fair plasticity. The bricklets had an air shrinkage of 4%, and the briquettes had a low tensile strength of 36 to 42 pounds per square inch.

Incipient fusion took place at 03, vitrification at 3, and viscosity at 6. The total shrinkage when the vitrified condition was reached was 11%, the color being deep red.

An analysis of this material yielded to A. N. Clark:

Silica	58.70
Alumina	18.31
Ferric oxide	7.19
Calcium carbonate	1.80
Magnesium carbonate	.98
Alkalies	3.67
Water and organic matter	9.35
	100.00
Ferrous oxide	2.73
Total fluxes	13.64

Among the brickyards are:

(a). Warren's brickyard, Badaxe, on the east branch of the Pinnebog River, on the south half of the southeast quarter of Sec. 13, Colfax, T. 16 N., R. 12 E. This brick has been used for the jail, schoolhouse and private houses and banks in Badaxe, and the Wadsworth schoolhouse, and has been shipped as far as Port Austin, Harbor Beach, and Gagetown. The color varies from cream to red. The red are the outside of the kiln, the white inside, and the sandy clay under the main clay bed which is somewhat used also makes a whiter brick. Toward the top of the burning they become chalky, the top one or two layers of each burning being spoiled with the amount of mineral in the water. Of the refuse brick the better are used for scoving, i. e., outer casing of the next burning. The section of the clay used is:

One foot of clay loam, beneath which are 5-6 feet of clay, then sandy clay.

This clay is not directly connected with the present Pinnebog, but may probably date back to the time of the Forest Beach. About a quarter of a mile west of the road on the east line of Sec. 13, it is said to become very bouldery with Canadian hardheads,—one or two as much as six feet long,—an old boulder bench.

In this yard the limestone pebbles are not as much trouble as the mineral water, i. e., soluble salts, the remedy for which Dr. Ries gives in his report, Part I. of Vol. VIII.

The yard has been at work some 13 years. In 1895, 300,000 brick were burnt, and it is thought to have averaged about 250,000 brick a year.

(b). Elkton brickyard, Ginter and Heist, on the southeast quarter of the southwest quarter of Sec. 3, T. 16 N., R. 11 E., near the west branch of the Pinnebog. Here the clay is directly from the valley of the Pinnebog, and is probably an alluvial clay, the section being 2½ feet of dirt, under which lie 4 feet of clay.

At the south end is a bed which yields a light orange red brick (Sp. 19228), while the ordinary brick is of a cream color like Sp. 19223. Probably in the former bed some of the lime which neutralizes the coloring matter of the iron is leached out. They are more or less bothered with limestone pebbles, causing a loss in burning (Sp. 19224). The product in 1896 was 500,000 brick. The brick has been shipped as far as Unionville and Fairgrove, and may also be seen in J. Ryan's house in Badaxe.

(c). Sebewaing brickyard, Ernst Reinhold, on the southwest quarter of the southwest quarter of Sec. 9, T. 16 N., R. 9 E.

This yard is close to the valley of the Sebewaing and gives a red brick. They are removing the pebbles by washing. See report on clays and shales by H. Ries Vol. VIII, Part I, which also gives illustrations, as follows:

Sebewaing.

"The surface clay used at the Sebewaing brickyard is a river clay, and is overlain in places by dune sands. The upper two or three feet burns red, while the lower clay in the bank is very calcareous and burns buff. Both clays contain large quantities of lime pebbles, and they are especially numerous in a layer at the juncture of the two kinds of clay. In order to eliminate these from the red-burning clay it is treated to a washing process, which consists in putting the clay into a circular sheet iron tank, with water, and the mixture stirred by arms attached to a vertical shaft. The effect of this stirring process is to get the clay particles in suspension, while the sand

and concretions fall to the bottom of the tank. In front of the machine is a screen with half inch meshes, through which the washed and suspended material is discharged into a trough about 50 feet in length. At the end of this trough is another screen with one quarter inch meshes. After passing along this trough most of the sand is dropped, and the clay and water flow out into the settling tanks which have wooden sides and a sand bottom. The water evaporates from these and leaves the washed clay forming a layer about six inches thick in the bottom of the trough. While the clay is settling and drying in the trough the material being discharged from the machine at a later period is conducted into a second or third trough.

"It is stated that two men can put enough clay for 16,000 bricks through the machine in one day. This ingenious washing process is a highly important one, and could be utilized at many other localities in the state where there are red burning clays containing lime pebbles or concretions. It furthermore removes the coarse sand from the clay and permits of the production of a much smoother brick, a point which is serious when front brick are to be manufactured.

"At the Sebewaing brick works the clays are molded in a Quaker soft mud machine, dried on pallets and burned in scove kilns. While the product is chiefly common bricks still some pressed bricks are made in various shapes and sizes. Their surface is, however, unfortunately roughened by the use of very coarse molding sand."

The burnt product is shown by Sp. 19229 and the clay, which is coarser and sandier than some of the other clays, by Sp. 19230.

The following is the result of some absorption tests on bricks of this county which shows a high ratio.

Number of specimen	19168	19225	19226	19227
Locality.		Elkton yellow.	Elkton red.	Sebewaing red.
Absorption rates, i. e., ratio of weight wet to weight dry	1.25	1.29	1.17	1.17

(d). In the lower valley of the Pigeon, on the southwest part of Sec. 13, T. 17 N., R. 10 E., Caseville, New Hayes, P. O., Chas. F. Leipprandt had a brick and tileyard which he afterward sold to Chas.

(?) Steinman who moved it to the southeast quarter of the same section. This yard also yielded a red brick. There are numerous other places along the river valleys where clays equally well suited for brick making may be found. There are some not far from the town of Pigeon. These river clays are, however, quite variable in character. It is not likely that any of the surface clays will be free from limestone pebbles, and as adjacent counties are at least as well supplied with such material, that any brick made from them will find a very wide market. See p. 213 regarding paving brick.

§ 6. Road metal.

There is no feature more marked in the recent development of the United States than the attention paid to better roads. In view of the recent development of the bicycle industry, and the figures showing what a large proportion of the cost of shipping wheat to Liverpool comes in getting it to the railroad, the attention paid is amply justified. A few notes on the care of the roads may be of value. See also Part I of this volume. The essential thing in a good road is that it should be well drained, i. e., with a coarse and porous underpinning, and with a hard surface not likely to soften when wet. The cementing properties of limestone are valuable to produce the latter feature. There is ample material in the county for making excellent roads. The sandy roads of the shore should be mended with a clayey material. Clay is not bad; shale or argillaceous limestone is better. Around Sebewaing the burnt waste of the coal mines is used with excellent effect,—the best material of all. (Sp. 19236). In Missouri clay is burnt expressly for road material. Burnt brick waste will not be bad. An excellent road may be made from the limestone waste, though somewhat dusty.

In general, however, the roads tend to be too clayey. For such roads coarse gravel is a good material for road mending, and the old Forest Beach shore lines described in a previous chapter and more elevated gravels furnish excellent material which is largely drawn upon. The coarse material is better for road mending and is also good ballast for railroads. The presence of a considerable amount of lime and iron is of value as adding cementing power. Between 60 and 118 feet above present lake level are numerous other generally more sandy deposits. The Bayport limestone is largely crushed for macadam. Crushed boulders would also be excellent.

The possibilities of making paving brick have not yet been developed, but I may say that it is to the shales of the coal measures or Coldwater series of the eastern coast that I should look.

Dr. Ries makes the following report:

Sebewaing.

"The Michigan Standard Coal Co. has a shaft at the southern end of the town at which the coal is interbedded with shale.

"That over the coal is a brittle black bituminous shale with numerous nodules of pyrite, while that under the coal is gray and sandy. On exposure to the air it slakes readily to lumps the size of a hazel nut, but to get it finer requires grinding. Some of it was tried at the neighboring brickyard, and it was not found possible to melt it in the scove kilns.

"It was consequently thought desirable to test it physically.

"The sample collected (182) gave no effervescence with acid, and slaked very slowly in water. When mixed with 17% of water it gave a mass of good plasticity whose air shrinkage was 5%, and the air dried briquettes made from it had an average tensile strength of 100 pounds per square inch with a minimum of 90 lbs.

"In burning, incipient fusion began at cone 1, with a total shrinkage of 8%, the color being buff. It vitrified at 5, and became viscous at 9. The shrinkage at vitrification amounted to 13%. The soluble salts were .25%."

§ 7. Limestone.

The other material that needs particular notice is limestone. This has been used not only in macadam, but also as paving blocks.

(a). Bayport limestone quarries. See pp. 110 to 112.

The quarries now operated are upon Sec. 5, Winsor, T. 16 N., R. 10 E. As we have mentioned, similar beds lie near the surface to the southeast and to the northwest and have been opened on North Island. The present location is exceptionally favorable as regards drainage. The section of the quarry is given in Figure 8, and the general extent of similar stone may be seen on Plate VII the part above the 620 foot contour in the neighborhood being especially to be noticed. A number of test pits near the Shebeon on the east half of the northwest quarter of Sec. 14, T. 16 N., R. 9 E., show similar limestone, but at a lower level where the water would be more in the way.

An elaborate illustrated description of these quarries appeared in Stone for August 1898, by A. C. Benedict.

The main products of the quarries are limestone which is burnt into lime, paving blocks, crushed stone for macadam, and building stone. The top layers appear to be least magnesian, and hence best for lime. The analysis published in Vol. V, is from layer No. 1, p. 110, as follows:

Silica	3.330
"Oxide lime and alumina" (should be iron instead of lime)	1.334
Carbonate of magnesia	.944
Carbonate of lime	91.538
Phosphorus and sulphur	traces
Organic matter and loss	2.854
	100.000

(Quicklime, 51.29.)

With so low a percentage of magnesia, the lime will be a hot strong lime which will take much sand. Prof. Langley of Pittsburg says: "This is a very pure limestone and unusually free from anything except carbonate of lime. It contains nothing injurious to iron, and in my opinion will give entire satisfaction in the blast furnace." It seems as though picking of the upper layers might give the exceptionally pure limestone required in the soda ash business. The lower layers are undoubtedly more magnesian, and probably contain more bituminous organic matter. The percentage of $Si\ O_2$ is noteworthy. This is or was undoubtedly largely in the form of soluble, organic $Si\ O_2$ and some of the layers are saturated with it. It adds much to the hardness of the limestone and its availability for macadam, etc.

We quote from A. C. Benedict as follows:

"The upper sixteen feet in the quarries consist of even-bedded, homogeneous, tough, drab-colored limestone, followed by twenty feet of sandstone suitable for grindstones. This is followed by from thirteen to fifteen feet of fine brown-stone, which is underlaid by fifty feet of shale. A space of seventy-five feet was quarried to the shale for experimental purposes, and a fine quality of sandstone found.

The cuarry may be divided as follows:

Ledge No. 1. 4 feet thick; used for macadam.
Ledge No. 2. 3 feet thick; burned for lime," (No. 1 of Fig. 8).
Ledge No. 3. 3 feet thick; building stone," (Nos. 2 to 5 of Fig. 8).
Ledge No. 4. 3 feet thick; building stone.

No 1 is drab, or dove-colored limestone, very hard and tough, used entirely for macadam, for which it is eminently fitted. The ratio of absorption, as determined by Prof. J. B. Johnson, C. E., Washington University, St. Louis, Mo., is one-half to seven-tenths of 1 per cent. Prof. Johnson's conclusions, after an exhaustive study of this quarry, is as follows:

'This is the strongest limestone of which I have any record. It is as strong as the best granite. It is also impervious to water, that is, non-absorbent as granite, and will weather perfectly. It is also as heavy as any limestone on record and as heavy as most granites. It is, therefore, an ideal material for all building and structural purposes, as well as for roads and sidewalks. For dressed stone it is rather hard, but for rock faced masonry it is perfectly adapted. A macadam road constructed of this rock (Ledge No. 1) crushed, properly graded, and well rolled, would make the best possible road for the country, or for the smaller cities and towns; and for cement sidewalks, a concrete made up of this rock crushed fine and used with Portland Cement, would be as good as the best "granitoid" walk in which granite is used.'

"Two carloads of Belgian blocks were placed in Tilden street, Saginaw, Mich., at the east end of Johnson street bridge across the Saginaw river, about eight years ago, and Stone recently examined this work and can testify that neither the traffic they have carried nor the elements have had an appreciable effect on them, except to make the top a little smoother than when fresh from the quarry. A material with this record certainly merits the careful investigation of users of this class of stone."

For macadam we need a tough non-porous, hard rock. Tests (Table II, p. 90) agree with Johnson that the Bayport limestone is in many layers practically non-porous, the water of the formation finding its way either in dissolved crevices or in the sandy layers. An excellent test of the utility of the rock for paving and macadam may also be found from its behavior under the drill. If with a core drill or churn drill progress be slow, and especially if with a core drill there be a large percentage of core saved, which comes out in large pieces, the indications are good. For example out of the first 28.3 feet drilled in the quarry hole No. 1, the aggregate of core saved was 18.4 feet, a portion of this loss being of earthy deposits between layers. In the lower grindstone layers more than half the core was lost, as this comparatively soft rock was broken up. A high crushing strength is also a desirable thing. A test at the Watertown Arsenal by Capt. Butler gave a crushing strength of 26,110 lbs. The weight was given as 170 pounds per cubic foot and specific gravity 2.72. A detailed description of these tests is quoted by A. C. Benedict in the article referred to. The specimen was 2.61 inches thick, with a compression surface of 29.65 square inches. It is true, however, as of all limestones, that this limestone is softer than iron and hence every concussion with iron wheels scrapes off a minute portion of white calcareous powder, so that such macadam tends to be dustier than that made from the more silicious rocks. Rain will dissolve this powder and soak it down to cement the macadam. In the opener country this dust will soon be dissipated, but in the city it may be unpleasant. Watering with the mother liquor of brines, or other solutions of salts that draw water would tend to check this tendency of this form of macadam. A number of the roads and the bicycle track near Bayport show what an improvement this macadam makes over clay roads. It has also been used in Saginaw.

This stone has been shipped quite a distance for building purposes.

We cite the following matter from Mr. Benedict's article. It must not be forgotten that his 3 and 4 are 2, 3, etc., of Fig. 8 and of Rominger's section.

"Nos. 3 and 4 are used for various building purposes. The following analysis, together with the tests relating to the crushing strength of the stone, show its value for macadam, paving blocks for streets, cross-walks, curbing, sidewalks, foundations, bridge piers, buildings, etc.:

Carbonate of lime	61.52
Carbonate of magnesia	14.50
Sand	20.85
Clay	2.04
Phosphate of lime	.09
Bisulphide of iron	.15
Water	.85
Total	100.00

"This analysis shows the stone to be a magnesian dolomite with an addition of a notable amount of sand which gives it an appreciable power to resist the action of the elements, and also the abrasive effects of travel where it is used for streets or sidewalks. The low per cent. of water, which is a measure of its absorptive power, renders it practically frost proof and gives it unusual value for all outdoor uses. It is very compact, tough, even-grained stone of drab, or dove-color, certain layers of which with age bleach to almost a pure white, resembling marble, but with this advantage over marble, that it is so close-textured that dust, soot, etc., do not adhere to it, but are washed off by rains leaving a clean, fresh-looking face at all times. Tested both artificial and naturally by freezing processes it resists admirably, showing its high rank as building stone."

The station at Flint and the offices of the Saginaw, Tuscola and Huron in Saginaw are examples of its use. I do not think that any limestone is a very satisfactory building stone in cities where soft coal is in use, as it soon becomes dingy, but the dove-colored shades of the Bayport limestone harmonize not unpleasantly with the dingier smoke-stained parts.

(b). Soule limestones.

As I have remarked, near Soule there are outcrops of argillaceous limestones of the Michigan series. A good part of Sec. 19 in Meade township is owned by the Michigan Cement Company, which beyond some test pitting has done nothing to develop the property. It is understood to be under the same control as the cement quarries near Milwaukee. As may be seen from Plates VII and VIII, the northeast quarter of Sec. 24, and Sec. 18, in T. 17 N., R. 11 E., and Sec. 19, T. 17 N., R. 12 E., seem also to be favorably situated for development. Elsewhere the limestone may be below water level, though it might be found northeast of Caseville adjacent to water. The limestone (Sp. 19009, 19103, 19104, 19105, 19222, 19223) is extremely like the Milwaukee stone in appearance. I quote from the report of the Wisconsin Geological Survey* the description which may be applied word for word to our rocks, of the Hamilton cement rock near Milwaukee, which occupies a limited area near the lake and immediately north of the city. "In general lithological characteristics, it consists of a bluish-gray or ash-colored, impure dolomite, which weathers, upon exposure, to a yellowish or buff color, owing to the oxidation of the iron which constitutes one of its ingredients. The

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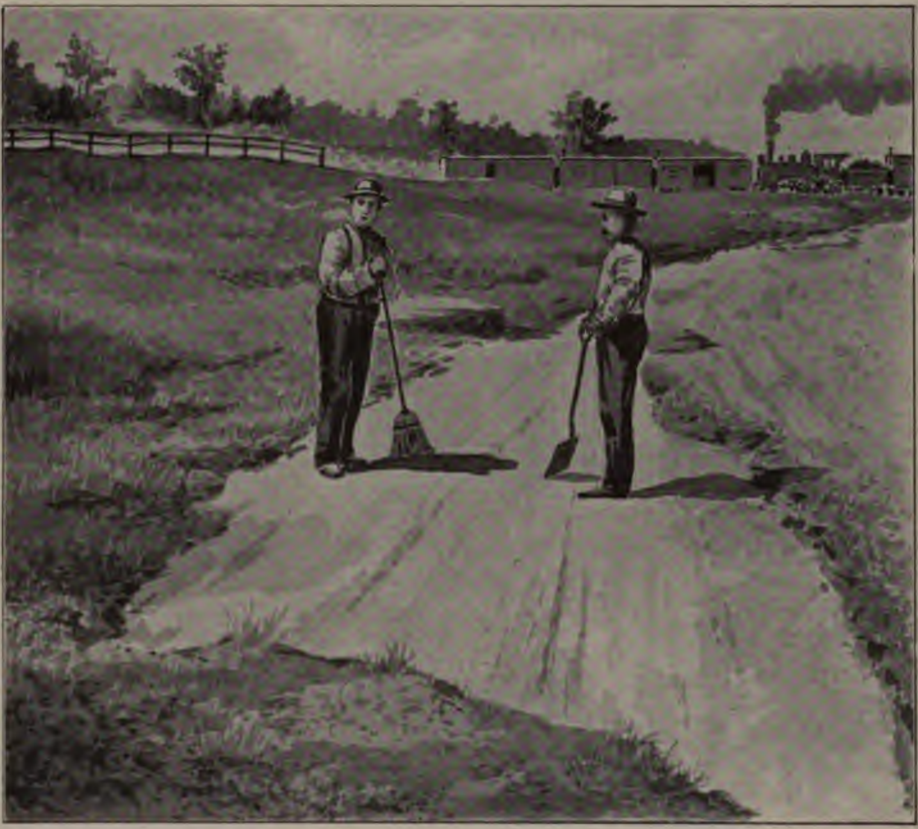
*Vol. II, p. 395.



GLACIAL STRIÆ AT BAYPORT QUARRY.

impurities consist chiefly of silica and alumina. The rock is characterized in certain portions by the occasional presence of cavities in which occur crystals of pyrites and calcite, and, very rarely, zinc-blende. Crystals of the two former minerals are disseminated more or less through certain portions of the rock. In texture, it is somewhat varying, being quite homogeneous in some layers, and quite irregular and lumpy in others * * * In degree of induration, it ranges from rather soft to moderately hard. The beds are usually thick, with the exception of some portions, which are somewhat shaly." In the same report on the following page (p. 396) will be found a number of analyses of cement rock. See also Part I of this Volume. No analysis of the Soule rock has been made to our knowledge, but a bed similar in horizon near Grand Rapids analyzed by Rominger has a good analysis for hydraulic lime. In general it may be said that in a good hydraulic limestone there should be about 21% of insoluble matter classed as clay. This was told me by very successful manufacturers in Germany who were exporting their product to the United States and this agrees very closely with the proportions in the analyses of the Milwaukee rock. It must be remembered that common clay is largely finely divided silica (33%), with some hydrous silicate of alumina, so that most of the 21% will be silica. The percentage of carbonate of magnesia is generally considerably less than two-thirds that of carbonate of lime. Just at present, however, the manufacture of Portland cement, in which the exactly right ratios are obtained by mixing, is replacing that of rock cement.

Success in the manufacture of hydraulic cement means much more however, than merely finding a suitable stone. It means constant watchfulness, and continual analysis to secure a uniform composition, through grinding, and proper burning, and this is also true of Portland cement.

§ 8. Coal.

The thickness of the principal seam is from four to two feet and less in the area of the coal basin, and above it there are indications of a thinner seam. It is at times cut off by sandstones as previously described. The depth is from 80 to 120 feet, and the deeper we find it the more likely it is to be thick. The water which is associated is a serious detriment, but as I have said, I do not think it comes from above. If I were working I should be careful to avoid sandstones, either above or below, but I had as lief work under the lake as not. In fact on some accounts I think that the coal might be thicker close to the lake to the southwest. All artesian wells like that at Oak Grove and the neighborhood for example, should, however, be cased off and avoided.* The main objection to the Sebewaing coal is its sulphur. The Sebewaing Coal Company say that their coal contains about 3% sulphur, and analyses of the product of the Saginaw Bay Coal Company are similar (Nos. 1 and 2 below).

TABLE IV.—TESTS OF SEBEWAING COAL.

	1.	2.
Moisture	4.46	4.82
Volatile carbon	47.92	44.58
Fixed carbon	40.45	41.52
Sulphur	3.06	3.38
Ash (probably mainly iron)	4.04	5.70
	99.93	100.00

Number	3.	3. Figured Dry.	4.
Location	Michigan Standard, Sebewaing.	....	....
Sp. Gr.	1.34	....	....
Moisture	6.09	....	41.39
Volatile Combustible	39.59	42.20	
Fixed Carbon	46.06	49.00	50.28
Ash	8.26	8.80	8.33
Sum	100.000	100.000	100.000
Total S	5.72	....	5.80
S in ash	0.04	....	0.05
Volatile S	5.68	6.05	5.75
S from Fe	....	....	6.52
Fe	....	....	5.71
C	68.07	72.49	....
H	5.26	5.61	....
N	1.49	1.59	....
O	5.15	5.48	....
Obs. with Calorimeter. Calories of heating power	7,070	7.520	....
" " " B. T. U	12,714	13,538	....

1 and 2. Saginaw Bay Coal Co., Vol. V, p. 84.
3. By H. J. Williams.
4. By C. H. Hilton.
This coal yields a coke of small volume fairly well fused. It is a coking coal.
Sample taken by H. Ries.

Since in 100% of (marcasite) sulphide of iron there are 53.3% sulphur and 46.7% iron, if all the sulphur of analyses 1 and 2 comes from sulphide of iron there would have been 5.74 to 6.36% marcasite associated with the coal and the iron therefrom would when burned to $Fe^2 O^3$ make 3.82% to 4.23% of ash.

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*Since writing the above an artesian well has burst into the coal mine at Sebewaing, making much more pumping in 1899, and the Sebewaing Coal Co.'s mine has been drowned out.

It is to be presumed that masses of solid "sulphur" or marcasite, such as often occur, were rejected, from analyses 1 and 2, as they are from the coal shipped. In the analysis of the Michigan Standard Coal above no such pains was taken, as the object was rather to get a fair sample of the coal seam as it occurred rather than as it was shipped. The marcasite if burned gives off much heat, and in fact it often catches fire spontaneously in the piles where the refuse to sulphurous coal is dumped. But while such coal makes a very hot steam coal (and tests have shown it to compare favorably with Ohio coals), the corrosive effect of the sulphurous fumes is disagreeable, making it unfit for gas making, passenger service, etc. The heating power measured in British Thermal Units, computed from the proximate analyses by the formula:

Heating power in B. T. U. = 146 (fixed carbon) + 147 (volatile carbon) + 40S would be: — 13,520 B. T. U. for No. 1; 13,210 B. T. U. for No. 2; and 12,767 B. T. U. for No. 3. This formula is an average one for Michigan coals. Kent's formula would give from the proximate analysis of No. 3 but 11,367 B. T. U. Dulong's formula would, however, from the ultimate analysis of No. 3 give 13,037 B. T. U. for the heating power of the same. The Sebewaing coal runs higher in volatile carbon and hydrogen than the Saginaw coal, as well as in sulphur.

At one time in the Jackson mines the miners were paid five cents a ton more for the "sulphur" or marcasite than for the coal. This sulphur is used in acid making, and it might be used in a fertilizer factory, but as there is a great deal to be found elsewhere, it could hardly be exported far. The most promising way of utilizing it would be in connection with some local industry or bone factory.

The Saginaw Bay Coal Company was the earliest producer, but was closed down by water. The Sebewaing Coal Company was still at work when the report was written, but succumbed to the same difficulty February 27, 1899. Maps have not been kept, but from the recorded output, and what I could learn of the thickness and extent of the workings, I have constructed a dotted line which may show the area within which the workings probably lay in 1897, within which area caution should be observed as to sinking wells, or in advancing from any shafts hereafter to be opened. The field has been taken up by the Michigan Standard Coal and Mining Co., to whose manager, X. B. Konkel, we are indebted for information. The location of these properties is shown on Fig. 10. The Michigan Standard Coal and Mining Co. organized in October, 1898, and reached 4 feet 9 inches of coal at 92 feet depth on December 19, following. They have the coal rights for 300 acres which is said to be covered by 7 to 17 feet of hard slate roofing.

TABLE V.—STATISTICS OF COAL PRODUCTION.

	Saginaw Bay Coal Company. W. L. Webber, Pres.	Sebewaing Coal Company. S. O. Fisher, Pres. W. T. Chappell, Sec. and Mgr.
1890		
1891	10,635	
1892	16,800	
1893	13,820	
1894		38,523

In 8 months of 1899 the Michigan Standard took out about 5,000 tons and are hoping to make it 20,000 in 1900.

The coal is used mainly by railroads and others, as steam coal, and the Dorrance grate is especially recommended for use with it since with so much sulphur it is bound to run on the grate. No attempt has been made to use the associated clays, the only thing of the sort having been the use of the refuse for mending the adjacent sandy roads, for which it is well adapted, nor has the associated sulphide of iron been used. For farther description of the coal basin see § 2 of Chapter II, § 5, of Chapter V, and the records of borings in Sec. 7, 8, 17 and 18 of T. 15 N., R. 9 E. These records we have leave to publish now as the coal lands are pretty well known, and the records throw light on the prospects for water, and for shale industries, pyrite, etc.

§ 9. Ores, sulphides of iron, zinc and lead.

(a). Sulphide of iron, pyrite and marcasite.

The metals are frequently associated with sulphur as sulphides in nature, and these sulphides are frequently mined. The sulphides of iron have never, however, been utilized as primarily sources of iron, but as sources of sulphur or rather sulphuric acid they have a certain value (about $4.00 to $6.00 a ton at factory). I have already mentioned that they occur with coal, and it is as a bye product of coal production that it is most likely that they will be of economic value. But they are by no means confined to the coal. They occur abundantly throughout the formation, nodules are common in the lower shales, and as already mentioned the sandstones of the Point aux Barques lighthouse are heavily charged with them. It is very common also to strike them in the wells, but from the nature of the case one cannot be sure whether the body struck is merely a nodule, i. e., irregular rounded mass, a form in which they frequently occur, or whether it is a more extensive bed. The top of the Napoleon sandstone is often heavily charged with sulphides of iron, and it will be noted that many of the wells around Tarry in Fairhaven township report considerable bodies of pyrite. The samples from these wells in Fairhaven township also show much pyrite. The sulphide of iron is likely to occur with the sulphides of zinc and lead, and when it does so occur it lowers the value of the others. The sulphide of iron must itself be quite pure to have any commercial demand.

(b). Sulphide of zinc, i. e., sphalerite, black jack or blende.

Small quantities of this mineral are very widely disseminated through limestone. It has a resinous lustre, good cleavage, and the powder has a dirty brown color, generally speaking. It is easily scratched with a knife. The lustre is so bright that a casual glance may not distinguish it from the sulphide of lead or galena, though they are easy enough to separate (p. 230). This mineral occurs in some quantity in limestones, probably of the Michigan series, in the adjoining county of Tuscola, near Cass City, and occurs as a mineralogical curiosity in Huron county (See Chapter VIII). Among the borings from Bauer's well, Sebewaing, I saw fragments from a cavity 118 feet down, i. e., near the top of the Bayport limestone, that showed specks of zinc blende.

(c). Sulphide of lead, galena.

This mineral has nearly the hardness and color of lead, but breaks into square angled pieces. At the time I was in Huron county there was quite an excitement as regards lead mining, and some explorations were carried on by Chas. Henning of Saginaw and others, with no success that I at present know. Since I made my examinations there have been reports of further explorations. The origin of the search for lead seems to be traditions of Indians finding it, so that it seems to be worth while to sift these traditions, and see what they are worth, and what the real prospects are.

The traditions all agree that the Indians went off into the woods and would not allow themselves to be followed, but came back with lead that they said they had obtained. Now as the reduction of lead from galena is extremely easy this is not intrinsically improbable. From Port Austin they are said to have been gone three or four days and the direction they look led people to think that the lead ore was obtained along the Pinnebog. From Heisterman's Island they are said to have gone across to the main land. There are numerous reports as to their having been offered large sums to reveal the place.

Dr. W. C. Wright of Unionville, gave me a piece of galena, which he obtained from an Indian halfbreed in the winter of 1888, who said it came either from near the Shebeon or from a place where the Au Sable River cut through the formation.

Before we speak of the Indians farther we will take into account a few other facts.

Around Mosner's hotel were a number of pieces of galena which were said to come from near Shebeon.

Mr. George Schuch is said to have found a piece of galena in digging a well 18 feet deep in the drift, on Sec. 21, T. 16 N., R. 9 E. Mr. Lambert of Caseville, said he picked up a chunk of galena as big as your fist near the mouth of the Shebeon, on Sec. 11, T. 16 N., R. 9 E. Some of the samples from Collison's well on Sec. 15, T. 16 N., R. 9 E., show galena. (See record.)

Finally, I have seen a piece of lead, not lead ore, which was said to have come from a test-boring. This may have come thence, but must have been put there first. It is easy enough, not merely for the driller, but for any mischievous boy or anyone else, in any way interested, to drop something down a drill hole. We have therefore to take the evidence of churn-drill powder with caution. So, too, an Indian might be tempted to "fill up" an interviewer, especially if he thought the compliment might be returned and he himself filled up. Such a tale as that an Indian off hunting struck his tomahawk into an apparent stump to hold it, while skinning game, only to find a solid mass of lead, betrays itself as a work of overbold imagination.

But on the other hand we must consider that the reports unite in directing suspicion on the same formation, the Grand Rapids group,

—the Upper Mississippian,—the reports being without collusion, and by persons unacquainted with the geology, and that the samples of galena agree physically, being of the coarsely cleavable variety. When we consider, too, that zincblende, which is a common associate of galena is known to occur in this formation, and that the Upper Mississippian itself is in Missouri and elsewhere a well known producer of galena* we have a strong presumption that the Grand Rapids group is in Michigan also somewhat galeniferous. But in searching for deposits we must remember that Indians rarely if ever, mined, certainly never test-pitted, and what galena they may have obtained was almost certainly obtained from the surface. Again an Indian's time was worth very little, especially if in a congenial occupation. It is quite as likely as not, therefore, that they obtained their galena from the beds of streams or other surface deposits where experience had taught them it was to be obtained. Mr. Lambert's discovery and the Collison well samples, taken in connection with the fact that the Shebeon does cut down to the limestone, make that region, i. e., that colored on the map, Pl. VII, as underlain by the Michigan series or higher beds the most promising, but the plan of investigation which would commend itself to me would be that of panning, as the western miners do for gold, and seeing if the heavy residue at the bottom of such a pan showed signs of galena or rather of the heavy white carbonate into which it would be converted. At the same time it would be little extra trouble to watch the sand pump when a well is bored for water in the district most likely to show signs of galena, and perhaps sometime a well put down for water may show signs of galena sufficient to warrant the use of a core drill. I do not consider that the prospects of a paying lead mine warrant expensive exploration, or borings, for the express purpose of discovering lead, for the chances are decidedly that all the lead that has been discovered comes from pockets of no economic value. But any farmer's boy can do the panning suggested, and if the lower Shebon, Pigeon or lower Pinnebog gravels showed uniformly a considerable percentage of lead ore, the prospects for success would be improved. It is possible that the fissure which we have spoken of as cutting the Sebewaing coal mine, which seems to have concentrated the sulphide of iron along it, may lower down, where it passes through the limestone, have served as a channel for waters which may there have deposited the other sulphides. And so the fault suggested by Mr. Wallace on Sec. 14, T. 16 N., R. 9 E., if it exists even as a mere break, may serve equally as a channel for the waters which concentrate ore bodies.

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*Missouri Geol. Sur., VI, pp. 47, 150, 151, 157, 158, etc.

§ 10. Salt.

This was once a great industry and went hand in hand with the lumber industry, and as the one has declined, so has the other. The lumbermen are largely dispersed to Alabama, Minnesota, all over the United States, and the salt blocks are shut down. Only around Caseville, and around Owendale, does the lumber industry still linger. There was still quite a nice little area of pine to the east of Caseville, and some comes in from the south around Owendale. Flach and Conley of Caseville, have the only remaining salt blocks in operation in the county, when once there were over ten.

We give below a list of the companies, so far as we know, that have operated in the county. Up to 1887 Huron county produced about ten per cent of the product of the state. In the last decade it has dwindled to a mere local supply. We have endeavored to get the

TABLE VI.—STATISTICS OF THE SALT WELLS.

	Date.	Depths	Capacity.	Process.	
Tremain & Clark, Old Bayport, never in operation	1874	2,000	....	....	....
Frank Crawford, Caseville	....	(1)	....	....	...
		1,760	....	....	....
		(2)	30,000	steam	....
		(3)	....	....	....
		2,270	....	+pan	....
Pigeon River Furnace Co., (later Lake Huron Iron Company)	....	1,760	30,000	steam	3
Flach & Conley (formerly Curran, Flach & Conley)	....	1,800	....	steam	6
Williams, Eakins & Soule, Port Crescent	....	1,250	....	....	....
N. B. Haskell, Port Crescent	....	....	....	....	....
Ayres & Co., Port Austin	1863	1,198	20,000	pan	....
Ayres, Learned & Ayers (Skene well)	1875	1,226	....	pan	....
M. Carrington, Port Austin	....	1,200	....	pan	....
? Grindstone City	(1)	1,000 ?	....	....	....
	(2)	?	....	....	....
New River Salt Co., New River	....	1,029	15,000	pan	3
Port Hope Salt Co., (R. C. Ogilvie)	....	787	20,000	pan	3
S. Jenks & Co., Harbor Beach	(1)	715 or 702 or 900	20,000 to 50,000	pan later steam	.... 3 ....
Huron Dairy Salt Co., 1886	(2)	1,920	....	....	....
Thomson & Bro., White Rock	(1)	555	20,000	pan	6
	(2)	700	....	....	....
	(3)	1,311	....	....	....

product more precisely, but have not been able to. The reports of the commissioners of mineral statistics have some misprints that we cannot straighten out.

The analyses of Chapter VI, p. 135, show the chemical nature of the brines. It will be noticed that the deep Harbor Beach well has a much larger proportion of other ingredients to the Na Cl (pure salt) than the brines from the Berea grit. This is also true comparing it with the shallower well at Harbor Beach, in which the Na Cl is over 98% of the solids (analysis 4). Though the wells at Caseville have not been analyzed, so far as known, a similar condition is indicated by the fact that Crawford's deepest well, which went down below the Berea grit and corresponds more or less therefore to the deeper Harbor Beach well, gave a brine so much more impure that they had to wash the pans every 24 hours, and later every 12 hours, to get rid of the bittern (which contains the chlorides of lime, potash and magnesia), whereas before, i. e., when it was only 1700-1800 feet deep, such washing was necessary only every 48 hours.

It will be noticed how comparatively free these deep brines are from sulphates. Now Leipprandt's 100 foot well, on Sec. 13, T. 17 N., R. 10 E.), which was quite salt and has been used for making salt for domestic use, and is said to make a pure salt though it needs to stand in the sun for a day to get rid of the iron (this is necessary for all brines), gives a strong reaction for gypsum, and this is characteristic of all the shallow salt wells.

In view of the vast fields of rock salt that have been discovered elsewhere in Michigan, which though they probably underlie Huron county, are many feet deeper than the deepest well, and in view also of the departure of the lumber industry, it is not to be expected that there will be any great revival of the salt industry. At the same time it will probably continue to supply a local demand unless crushed by some large association. The surplus is shipped outside, but the profits come from the local trade. Nothing has been done yet toward saving the by-products, the plaster and bitterns, and it is in that direction we must look for progress in the future. I have already suggested that there might be enough bromine and potash in some of the bitterns to pay for extraction, and it seems as though some of the bitterns might find uses as a base for disinfectant manufacture, etc. The calcium chloride has been used in putting up canned fruit, and the county is an admirable fruit raising country. It is also used with water glass in making artificial stone.

The use of the refuse salts as fertilizers has a limit in this county owing to the fact that in the western part the soil is already rich in the same substances, but on the sandy strips, and in connection with manufacture of bone fertilizer and the use of the sulphur of the mines, there seems to be an opening for their use.

§ 11. Gypsum, or plaster of Paris.

This mineral is white when pure enough to be valuable and cleaves into scales of transparent friable flakes. It is soft enough to scratch with the finger nail.

Just across Saginaw Bay the gypsum quarries of Alabaster and Tawas Bay have long been known, but while it has early been observed by Rominger that the strata ought to extend into Huron county, but little has been known definitely in the matter. Here and there wells were supposed to have encountered gypsum, but drillers are likely to overlook it, when not going down to find it.

The work of the survey has put it beyond question that at least one considerable bed of gypsum does extend into the county and its probable extent is shown by a line upon Plate VII*, but it is nowhere exposed at surface. The few fragments of gypsum we have seen (Sps. 19004 and 19159) only show that there is some of good quality, but what the thickness of any certain grade may be, we do not know. So far as we can judge, it is everywhere covered too deep to permit of working by stripping and open quarrying but the southern part of Sec. 23, Chandler, and the neighborhood of Tarry near the center of Fairhaven, seem as good places to test as any. There has been quite an inquiry for plaster lands lately, but in view of other deposits, better known and quite as well located, the prospects are not too flattering. At the same time I doubt not that some time this resource of the county will be developed, when the prospects for pecuniary success are favorable, and it is certainly advisable that in all well-drilling throughout the district where the gypsum is liable to occur as shown on the map (Plate VII) an eye should be kept out for it, and as good samples as possible kept, as well as an idea of its thickness got, for its own sake, as well as to keep it out of the water.

§ 12. Marl.

Marl or rather bog lime is a white or bluish gray substance slimy and sticky when wet, powdering when dry, which effervesces violently and dissolves largely in acids, and is found beneath lakes, ponds or marshes, and is often full of little shells, such as those listed in Chapter 10, § 2. Generally speaking, throughout the state the well and ground water contains considerable lime dissolved in the water as bi-carbonate. When this water finds its way by springs into ponds or marshes the carbon dioxide may be abstracted by plants (Davis), or sometimes escape directly, and carbonate of lime may be extracted by animals or precipitated directly if the loss of carbon dioxide to the vegetation or the atmosphere is sufficiently great.

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*See above Chap. V, § 3, pp. 100 to 103.

It has long been recognized as a fertilizer, but usually the solids of Huron county have sufficient lime and its main application will be upon very sandy or sour soils. As a fertilizer no great purity is required and in fact most dictionaries refer to marl as a calcareous clay.

A new and important use for it has, however, sprung up in the manufacture of Portland cement. For this purpose it is wanted to be as pure $CaCO_3$ as possible, so that just the right proportions of clay can be added to it to make the best composition. Practically the dry marl should be not less than 9-10 $CaCO_3$. I have seen no marl as pure as this, but there are signs of the presence of marl in the marshes back of the Forest Beaches from Mud Lake to just south of Badaxe, and clear around to Ruth. It might be well to explore farther, as if there were much marl, especially just north of Ruth it could be worked in connection with the shale banks of White Rock.

Some other localities for marl are mentioned in the reports of various wells e. g. § 20, Hume township.

CHAPTER VIII.

NOTES ON MINERALS.

§ 1. Introduction.

It is the object in this chapter to gather together notes on the minerals as such. The mineralogy of the county, if we leave out of account the minerals that may occur in the drift, is very simple, and it would be possible to make it quite complete. But I have thought it would add to the utility of the report to the residents of the county, if I added few notes on the minerals which make up the rocks that are scattered as boulders upon the surface. As we made no extensive observations upon the drift, and almost any mineral rock or fossil that occurs in Canada or the whole lake basin is liable to turn up, transported here by the ice of the glacial sheet, or of the spring floes that drift here and there as the winds impel, this part of the work is very incomplete. I have arranged the work in this way. I have given each mineral a heading, taking them in the order in which they occur in Dana's mineralogy, and then taking each variety or different form of occurrence, have given briefly such characters as have actually been observed on Huron county specimens, and then appended the locations where the same were found.

§ 2. List of minerals.

Copper.—Copper-colored; can be cut, has a shining streak, tarnishes dark, and is likely to have greenish spots.

Mr. W. L. Webber has a piece about two ounces in weight which was found at the bottom of the stripping on top of the rock at the Bayport quarry. The stripping is of lake gravel, a water stage just above Lake Algonquin. The connection by water through to Lake Superior at this time is suggested. Label: "received March 10, 1887, from A. H. Wallace." The crystals of native copper referred to by Winchell (1860, p. 80) have not been verified.

Galenite. Pb. 86.6%, S., 13.4%. Lead-colored, metallic, easily cut, heavy, brittle, breaking into cubical pieces, weathers so as to have a yellow coating. The occurrences have already been described in Chapter VII § 9 (c). None of them are satisfactorily authenticated, that is, there is no place where one can go back and be sure of finding even a very little galena. All of the finds may have been from drift deposits, except that in Collison's well. Galenite is most liable to be found in small vugs or cavities in the limestone.

Sphalerite. (Zn 67%; S. 33%). Lustre resinous to almost metallic; color deep yellow to black; very cleavable, the directions of cleavage being at angles of 60°. streak rather dirty.

Found in the drillings from Bauer's well at Sebewaing; also (Sp. No. 19066) traces near the Point aux Barques lighthouse, with calcite replacing a shell; liable to occur under same conditions as galena.

Chalcopyrite? Cu 34.5%; Fe 30.5%; S. 35.0%. At the Point aux Barques lighthouse some of the pyritic matter seems from the copper blue-green weathering stains to show traces of copper, but the mineral as such has not been recognized.

Pyrite. Fe 46.6%; S. 53.4%. Brassy; in cubes or pentagonal dodecahedra, harder than a knife but brittle; powder greenish to brownish black; less decomposed and somewhat more yellow than marcasite, but also weathers fairly readily to sulphate of iron, or to hematite, in which case the rocks containing it smell sour and taste puckery. While pyritic matter is common in all the formations it is generally of the allied species, marcasite, which has exactly the same chemical composition but a different crystalline form, a lighter color and a greater readiness to change to sulphates. At the same time the two seem to be often intimately associated. I have pieces of coal in which marcasite seems rapidly to change to vitriol, while pyritic coatings on the faces near by remain untouched. Occasionally it occurs in vugs in the sandstone (Sp. 19011) in quite good sized crystals.

Marcasite. Like pyrite, but differing in crystalline form, and more readily decomposed. Some of the specimens appear very white on fracture, which suggests a trace of arsenic.

Abundant in the coal mines of Sebewaing, occasional in the limestones of Bayport, etc. Abundant in the shales in nodules and especially so at the Point aux Barques lighthouse, sometimes cementing the conglomerate.

Quartz. Si 46.7%, O 53.3%. Rock crystal, etc. This is the principal constituent of sand, and makes most of the pebbles of the conglomerates and gravels, and is most abundant in the boulders, and, is usually either colorless, transparent, or white and milky. It is the hardest mineral commonly met, and a steel knife will leave a metallic streak on it, and there is almost no trace of cleavage, the fracture being commonly glassy. When crystallized, it has the form of a hexagonal prism with triangular faces making the termination. In this form it occurs in the nodules of Charity Island (Sp. 19191), but is absent or rare around Bayport in the nodules, though many of the fossils and corals are composed of quartz.

Chalcedony. A variety of quartz, with a waxy lustre, and bluish to white tints, tending to have a botryoidal surface (composed of little round projections like a bunch of grapes or raspberries). Most abundant at Charity Island (Sp. 19191), and liable to occur elsewhere in the limestone.

Chert. Opaque gray silicious nodules, with a smooth conchoidal fracture and somewhat splintery, often tending to weather out into concentric shells. Occurs in the limestone (Sps. 19002, 19179).

Hematite. .Fe 70%; O 30%: Red to steel-color; powder red. Occurs abundantly in the drift, associated with and coloring the blood red jasper which is so showy a constituent. It probably occurs at times as an alteration product of iron sulphides, but generally the mineral that results from these is limonitic, i. e., hydrous. Only once have I observed well developed hematite (Sp. 19020), near Hard Wood Point, lining a cavity. The bright metallic scales are arranged perpendicular to the walls of the cavity as in the specimens of grape ore that show a bloom.

The Lower Marshall sandstone is heavily charged with iron. Probably originally much was carbonate, but many of the flag layers have a blue or purplish color and give a red streak, showing that they are charged with hematite. Others are more altered and give the yellowish streak of limonite. (Sps. 19037, 19125, 19137, 19145.)

Limonite. Fe 59.8%; O_3 25.7%; H_2O 14.5%, Ochre and bog iron ore. Wide spread as iron rust, staining and coloring the soil and rocks. Davis has noticed that around the borders of bogs it is leached out of the sand by organic matter, to be deposited at the bottom. Specimen 19174 of bog iron ore shows the effect very characteristically. There are bright irregular seams which look like black varnish, yet give a yellow brown powder, embedded in a yellow brown ochre. The Marshall sandstones are often very heavily charged with limonite. Sometimes a concentric structure can be noticed, the original green or blue shale lying in the middle, while there are brown lines around it as the weathering to limonite works in (Sps. 19089—19094, 19069).

Wad. Impure ore of manganese. Specimen 19174 gives no reaction for manganese, but Sp. 19158, which is probably from Tuscola county and is a blue black earth with calcareous pebbles, does. Similar deposits might be expected near Soule.

Calcite. CaO 56.0%; CO_2 44.0%. Effervesces in vinegar; soft, being readily cut with a knife but not with the finger nail; cleaves readily into small rhombs with faces making an angle of about 75° with each other. Crystallized it occurs best developed in vugs or in nodules in the Bayport limestone (Sps. 19002 and 19005). In these cavities there are two forms side by side which look different enough to be different species: (1) Dogtooth spar, in small white pointed scalenohedrons; (2) Generally older, more transparent but brownish crystals, in which 2R is the predominant face, though a number of other faces, and a twinning also appear. These crystals from their brown color and occasionally iridescent tarnish would be taken at first for some other carbonate, but in reactions with acids and in specific gravity they agree with calcite, and not with the magnesian or ferriferous carbonates, so that the different appearance must be due to a trifling percentage of impurity (organic matter ?).

Calcite also occurs quite commonly in small crystals lining the cavities of fossils, especially in the chambers of Goniatites (Sp. 19010 and 19018).

Calcareous tufa, a recent deposit of calcareous springs, looks at first glance more like old bone than anything else (Sp. 19107). In a massive form calcite composes the limestones, and limestone pebbles are widespread through the drift. The outcrops of limestone have already been described.

The other carbonates, now that what I took to be ankerite proves not to be such, have not been recognized in crystalline form, though dolomite doubtless exists as does certainly the massive form.

Dolomite. CaO 30.4%; MgO 21.8%; CO_2 47.8%. Less briskly attacked by acids than calcite and slightly heavier; similar in cleavage and hardness. Certain beds in the Bayport limestones are decidedly dolomitic. Generally such beds are darker and browner.

Spherosiderite. Fe 48.3%; O 13.8%; CO_2 37.9%. Concretionary iron ore, characteristic of the Lower Marshall, forming balls which turn to limonite on exposure, always more or less impure and acting as a cement to the sand. Specimen 19011 shows the balls well, but many others of the Lower Marshall specimens effervesce slowly with acids, rapidly coloring the acid yellow.

Feldspars. Alumo-silicates of potash, soda, and lime, not quite as hard as quartz, generally white or light colored, with two cleavages which are not equally good and are at nearly right angles. Common among the drift pebbles, making with quartz the principal constituent of the granitic rocks. In the conglomerates it seems often to have changed to kaolin, and yet sometimes the feldspar is fresh enough so that the cleavage facets show well.

Pyroxene group, found in the drift only, in dark colored boulders.

Amphibole, or hornblende. Silicates containing alumina and magnesia, and usually iron, lime and a little soda.

A common, perhaps the commonest dark constituent of the boulders, usually dark green, giving a light powder, and showing a prismatic cleavage; gives a somewhat silky lustre when closely examined.

Garnet. Silicates of alumina, lime, and, in usually less quantities, of lime, magnesia and iron.

In small pink granules this is a common constituent of sand, and occurs in the drift formation. It is more marked in the residue left by panning.

Epidote. A silicate containing lime, iron, alumina and water; green to yellow-green, only in the drift, or in sand as yellow-green grains?

Mica. Silicates, containing alumina, water, and potash and soda or magnesia and iron, the darker ferriferous ones being often grouped as biotites and the lighter as muscovites.

Usually in thin flexible white or brown, silvery or golden scales well known as isinglass, sometimes mistaken for gold! The shales of the Marshall are generally exceedingly rich in mica, and scales of white mica (muscovite) may often be seen in the grindstones. The shales below the Marshall are even richer in mica, and the shales below the limestones at Soule are also micaceous. With quartz and feldspar it occurs in the granite boulders.

Also occurs in boulders of mica schist, etc., and with staurolite in staurolite schist.

Staurolite. (A silicate of alumina, magnesia, iron and water.) Occurs in prismatic crystals with an obtuse prism in front, frequently twinned so as to look like a St. Andrew's cross; scattered here and there on a fine grained micaceous ground in a staurolite schist in occasional boulders, as on North Island.

Chlorite. Silicates of alumina, magnesia and water, in green, flexible, not elastic scales in boulders. There are characteristic green stains in some of the limestones that seem to be due to some chloritic mineral.

Kaolin. Hydrous silicate of alumina. White; earthy smell; sticks to the tongue, soft; occurs after feldspar in rounded nodules in conglomerate (Sp. 19016).

Gypsum. CaO 32.5%; SO_3 46.6%; H_2O 20.9%. Cleaves into white brittle scales; soft, just scratched with the finger nail. In small crystals sharply formed like Fig. 1, under gypsum in Dana's System of Mineralogy, on shales in the Sebewaing coal mines, probably due the evaporation of the selenitic (gypsum-bearing) waters (Sp. 19233).

A piece from Sec. 16, Caseville, probably found in digging a well is satin-spar, with a satin-lustre, being an aggregate of parallel fibrous crystals (Sp. 19159).

Large rounded masses are found elsewhere in the drift digging wells. Being more or less soluble, it cannot remain very long exposed at the surface.

Melanterite. FeO 25.9%; SO_3 28.8%; H_2O 45.3%. In fibrous needles radiating from pyritic specimens of coal or marcasite; has an inky taste.

Occurs very abundantly on the specimens from the Sebewaing coal mine and probably occurs elsewhere on the nodules of iron sulphide. Another yellow iron sulphate, either copiapite or coquimbite, also occurs in similar circumstances.

Coal. Impure carbon; occurs both in the coal mines and in small pockets or coaly bits and fossils at various points in the Marshall series. The quarries generally show some slabs sprinkled with coaly bits. (Sp. 19015.)

One interesting occurrence already mentioned is that of a rounded pebble of bituminous coal in the conglomerate of Point aux Barques lighthouse (Sp. 19068).

The coal will generally differ from black shale by leaving, after it ceases to burn with a yellow smoky flame, a black residue which a lens shows to be full of bubbles, indicating that it has been melted. In any case if it is burned so that the residue ceases to be black, it will not amount to more than 20% of the whole. In black shale on the other hand the residue is apt not to be black, will retain the original shape of the fragment and be more than one-fifth of it in weight.

CHAPTER IX.

BOTANICAL NOTES, BY C. A. DAVIS.

§ 1. Geological, geographical, and practical relations of plant distribution.

The following list of plants is based on collections and notes made at odd moments and incidental to regular geological work, and entirely subordinate to it. The larger part of the work upon which it is based was done at Port Austin, outside regular hours of work. Moreover the territory assigned the writer for examination was a strip three townships wide through the center of the county and no study was made of the flora of the eastern or western sides except such as could be undertaken in a day at Harbor Beach in July and a few hours at Caseville and Bayport, late in August, hence the list must of necessity be incomplete and fragmentary and is published without any pretense of being complete.

It is, however, true that the sections of Huron county visited by the writer indicate that its flora is not very extensive or varied, as a large part of the county presents very nearly uniform conditions of soil and elevation, so that large areas are covered with a growth of practically identical species. The monotony of the vegetation is farther increased by the fact that a very large portion of the county has been devastated a number of times by fires, which have not only destroyed the primitive vegetation of the time when the fires occurred, but much of the vegetable mold as well, and with it the seeds and underground parts of the plants which might have survived the fires. As a result, these areas have been covered with a growth of such plants as could grow in rather thin light soil and whose seeds could reach the ground from a distance. Such areas must be seeded in two principal ways, by the winds and by animals, and of these two agencies, by far the most important is the wind. Hence we should expect to find those plants prevailing, whose seeds are easily carried by the wind, or whose fruits are attractive to animals, especially to birds. The woody plants whose seeds are capable of being borne long distances by winds are best represented by the poplars and willows, and of the herbaceous plants whose seeds are thus carried about, the common fire-weed, milk-weed and thistles are excellent examples. Plants whose fruits are attractive to birds are well represented by the wild cherries, various berries, etc. If we examine the tracts of Huron county which suffered most from the great fires, we will find that the flora is almost wholly limited to those species whose seeds have been planted in the ways mentioned. The trees are various species of poplars, sometimes mixed with birches, the shrubs, blackberry and raspberry bushes, and the herbaceous species are represented largely by such forms as Epilobium, Solidago, Aster and others whose seeds are easily borne about by the wind. Plants whose seeds are less easily carried about from place to place are rare or wanting in such tracts, wherever they are found, and in the region under consideration there are whole sections whose entire flora does not exceed twenty or thirty species, except in the stream valleys, where the fires did not burn so vigorously, or into which seeds have been carried from unburned districts by the stream.

Still another consideration limits the productiveness of such areas as those above described, namely, that the soil is capable of supporting only a limited number of individuals of any species, and those species which can best endure the hard conditions imposed upon them will occupy the entire soil and prevent the introduction of less resistant forms. In places where supplies of moisture and mineral food are limited as they are over much of this county, each plant has also to cover relatively a large area with its roots, hence the number of individuals is small as well as the number of species, and vegetation is not luxuriant.

Of the entire territory visited by the writer, the region along the shores of the Lake and covered by the sand dunes showed the least change either from fire or from cultivation and hence was of most interest. Here the conditions producing scant vegetation are intensified to such an extent that herbaceous vegetation is reduced to the minimum and the ground is covered only by such forms of plants as have especially developed powers of resistance. These powers may develop along several lines, but chiefly they seem to be confined to increasing the moisture-absorbing or root system and decreasing the moisture-exhausting or leaf system. Or, as in certain species, the vegetative processes may go on actively only during the cool moist portion of the year, the plant remaining nearly dormant during the hot dry summer months, or living on reserve food stored in some specially adapted part of the plant. Because of these modifications to fit the special environment, the plants of the dunes are of great interest to the botanist and are worthy of farther study. The flora of the dunes of Huron county is made up of: (1) plants peculiar to the shores of the Great Lakes; (2) those common to the shores of the Great Lakes and of the ocean; (3) those found on sand barrens generally; (4) those which have been introduced by the advent of white men; (5) northern species. The limits of the various groups are quite well marked and may be defined as follows: The plants peculiar to the shores of the lake and ocean are to be found only near the water, probably not much out of the range of the highest storm waves, and so far as observed in this county, never beyond the dune line nearest the lake or the most northern one. The sand-barren plants occupy the rest of the dunes, encroaching on the territory of the other groups frequently. The fourth class take up unoccupied portions of the land wherever they gain foothold. The northern species are found on the more exposed situations along the dunes.

A problem worthy of solution is that involved in the fact that a number of species of the shores of the Great Lakes are identical with those found in similar places by the Atlantic.

The formerly accepted theory that the plants growing along the lakes are survivals from the time when the lake was an arm of the sea, is no longer tenable in the light of modern investigations. The species from the two regions are absolutely identical and of comparatively modern and highly developed types, and must have attained their present forms long after all connection between the ocean and the lakes which would admit the passage of salt water had ceased. Moreover, these species when found on the sea shore are not usually found on soil that is saturated with salt water, as the salt marshes are, but on the contrary, are found growing on the sandy strip back of the beach, or, more frequently, on sand dunes. If the salt water ever reaches these situations, the salt is soon leached out from the porous sand by rains and the soil is practically as free from salt as on the dunes of the shores of the Great Lakes.

It would seem probable that these plants are capable of enduring the exceptionally unfavorable conditions under which they must establish themselves from the seed, with greater powers of resistance than other plants. These conditions in part would be exceptional sterility of soil, for on newly formed dunes there is scarcely a trace of organic matter, and soluble mineral matter must be present in very small proportion, since the sand of both lake and ocean dunes is largely composed of silica or quartz. A second condition is exceptional mobility of the soil. Even in a slight wind, dune sand is in some motion and under stronger gales it blows about, even when the rain is falling,to such an extent that a plant may be buried out of sight, or have nearly all the soil removed from around its roots in a short time. A third condition is the great porosity of the soil, which makes it almost impossible for water to stay in it at all, especially near the surface. But few plants would be capable of enduring one of these difficulties, and undoubtedly many an ambitious weed perishes in the attempt to place itself among the plants which can get a foot hold despite all of them. When once established from seed the shore plants are vigorous, growing plants sending strong, wide-spreading roots deep into the soil and searching far and wide for food. The beach pea, *Lathyrus maritimus*, for instance, has been known to send its underground stem more than ten feet through the sand horizontally, and the tough thickly matted roots or rootstocks of some of the dune grasses make the best possible protection for the sand against the wind. So well is this recognized in regions where the wind moves the sand from exposed dunes to cultivated tracts, as for instance, on the shores of Cape Cod in Massachusetts, that stringent laws are enacted against breaking the sod on those dunes where these grasses have become established, and the inhabitants devote a certain season each year to planting the grasses on threatening dunes, to prevent the drifting of the sand.

As to the way in which the seeds of the plants growing on both lake and ocean shores,traveled across the intervening land, it may be stated that migratory birds carry seeds of plants long distances, and this is particularly true of water fowl and wading birds, who carry seeds attached to beaks, feet and feathers,, in considerable numbers, and migrate freely from the ocean to the lakes.

In general the flora of Huron county is most closely allied to that of the Saginaw valley, not a single species which is characteristic of the flora of the southeastern section of the state having been noted. Certain northern species are abundant enough to warrant the assumption that a portion of the flora has come from the northern shore of the bay, or across the lake from the Canadian shore. This is easily explained when we remember that the migration of birds southward along the shore occurs at the time when the seeds of many plants are fully ripe and most abundant while the migration to the north occurs at a time least favorable for the transportation of seeds. The prevailing winds are also from northerly directions during the fall and it is quite certain as has been shown that they have much to do with scattering the seeds of certain types of plants. The evidence, geologically speaking, is that the lake currents run northward, not southward, along the shore of the county, and this taken in connection with the facts already pointed out in regard to the distribution of plants in the county would lead to the conclusion that such currents have little to do with carrying plant seeds. In this instance, however, the general law that such currents are important agents in distribution of plants is modified by the fact that only a few small and unimportant streams enter Lake Huron at its southern end, hence but small numbers of seeds are carried from the land into the lakes.

The importance of the wind as an agent of seed planting in isolated tracts of land is shown by the fact that Gull Island, a small tract of lake bottom exposed, near Port Austin lighthouse, by the late subsidence of the lake level, is covered with plants whose seeds are known to be disseminated by wind, only two species of a score or more noted, at the time of the writer's visit there, not being of this type.

The examination of the flora of Huron county made by the writer indicates climatic conditions which make possible the raising of nearly all the fruits which can be grown in the state, and the soil in many parts of the county is undoubtedly suitable for profitably raising all kinds of small fruits. Because of the northern location the ripening of these fruits is delayed beyond the season in the more southern counties and there should be a good demand for these late ripened fruits in the large cities. During the summer of 1896 there was a very large crop of fruits of all kinds in the older parts of the county and fruit trees of all sorts were thrifty and seemed unusually free from insect or plant parasites. The chief difficulties in the way of growing the more perishable fruits seem to be remoteness from markets and lack of cheap transportation, the latter especially.

§ 2. List of plants.

The nomenclature of the list here presented is that of Gray's manual, 6th edition, following for ease of comparison and the sake of those most likely to wish to use it, the order as given in Beal and Wheeler's Michigan Flora. From the fact also that Gray's Manual of Botany is still and must be for some time to come the most accessible work on systematic botany for students in the region covered by this list, this has seemed to be the wisest course to pursue in a list of this character.[*]

In conclusion the writer wishes to acknowledge the kindness of Prof. Charles F. Wheeler of the Michigan State Agricultural College, who has verified all doubtful determinations of species and rendered other valuable aid.

LIST OF PLANTS.

1. Anemone cylindrica, Gray. Longfruited anemone. Sandy pasture on the Lake shore west of Port Austin.
2. Anemone Pennsylvanica, L. Pennsylvania anemone. Low ground along streams.
3. Ranunculus sceleratus, L. Cursed crowfoot. Near a spring 2 miles west of Grindstone City.
4. Nymphæa reniformis, DC. Pond-lily. Tuber-bearing water-lily. Pinnebog River in Hume township.
5. Nuphar advena. Aiton. f. Yellow Pond-lily. Cow Lily. Common in streams.
6. Adlumia cirrhosa. Raf. Climbing Fumitory, Mountain Fringe. At the quarries, Grindstone City, on refuse piles. Also in talus of cliffs three miles west of that place.
7. Arabis lyrata. L. Common on the sand dunes along the lake.
8. Erysimum cheiranthoides, L. Worm-seed mustard. Near Port Austin on dunes.
9. Cakile Americana, Nutt. American Sea Rocket. Sand dune line nearest the lake. Not observed back of the outer row of dunes, and usually on the side facing the lake.
10. Saponaria officinalis, L. Bouncing Bet, Soapwort. Roadsides about Port Austin.
11. Silene antirrhina, L. Sleepy Catchfly. Sand dunes west of Port Crescent.
12. Silene noctiflora, L. Night flowering Catch-fly. Port Austin.
13. Lychnis Coronaria, L. Mullein Pink. Waste places, Port Austin.
14. Arenaria serpyllifolia, L. Thyme-leaved sandwort. Near Port Austin in barren sands.
15. Hypericum perforatum, L. Common St. John's Wort. Dry soil by roadsides near Port Austin.
16. Hypericum Canadense, L., var. majus, Gray. Crevices in the rocks on the lake shore near Port Austin.
17. Malva moschata, L. Musk-Mallow. Roadsides, frequent.
18. Malva sylvestris, L. High Mallow. Port Austin.
19. Malva rotundifolia, L. Common Mallow. Roadsides and waste places.
20. Tilia Americana. L. Basswood. Linden. Woods near Port Austin.
21. Geranium Robertianum, L. Herb-Robert. Along the Beach near Grindstone, also in rocky soil inland.
22. Impatiens fulva, Nutt. Spotted Touch-me-not, Jewel-weed. Low grounds.
23. Oxalis corniculata, L., var. stricta, Say. Yellow oxalis. Wood-sorrel. Common.
24. Xanthoxylum Americanum, Mill. Prickly Ash. Common in moist soils.
25. Vitis riparia, Michx. Wild or Fox-grape. Frost grape. Common along streams.
26. Ampelopsis quinquefolia, Michx. Woodbine, Virginian Creeper. Woods, Common.
27. Acer saccharinum, Wang. Hard maple, Sugar or rock-maple.
28. Acer dasycarpum, Ehrh. White Maple, Soft Maple. Low ground along streams.
29. Acer rubrum, L. Red Maple, Soft Maple. Moist woods.

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[*] A few unimportant divergencies from the order of Beal and Wheeler's flora noted in proof reading have not been corrected. Thus the following numbers should change places: 17 and 19, 48 and 49, 54 and 55, 224 and 225, 267 and 268, 281 and 282, 309 and 310. No. 30 should come before 35, 181 before 179, 183 after 185 and there are no entries 139 and 264. L.

30. Trifolium pratense, L. Red Clover. Roadsides and fields.
31. Rhus typhina, L. Staghorn Sumach. Common.
32. Rhus copallina, L. Dwarf Sumach. Sand dunes.
33. Rhus Toxicodendron, L. Poison Ivy, Poison Oak. Common in rocky places, and in the moist places among sand dunes.
34. Rhus venenata, DC. Poison Sumach or Dogwood. In swamp about Mud Lake, Grant township.
35. Trifolium repens, L. White Clover. Pastures, etc., common.
36. Melilotus alba, Lam. Sweet Clover. Waste places, Port Austin.
37. Robinia Pseudacacia, L. Locust. Port Austin, Huron City, Etc.
38. Desmodium Canadense, DC. Tick-Trefoil. North Charity Island.
39. Lespedeza capitata, Michx. Bush Clover. North Charity Island.
40. Lathyrus maritimus, Bigelow. Beach pea. Beach at Port Austin.
41. Prunus Americana, Marshall. Wild Plum. Hume township, along streams.
42. Prunus pumila, L. Dwarf Cherry, Sand Cherry. Abundant on the dunes west of Port Crescent.
43. Prunus Pennsylvanica, L. Wild Red Cherry. Common.
44. Prunus Virginiana, L. Choke Cherry. Common on the sand dunes west of Port Crescent.
45. Spirea salicifolia, L. Meadow Sweet. Low grounds, common.
46. Rubus strigosus, Michx. Wild Red Raspberry. Common.
47. Rubus villosus, Aiton. High Blackberry. Common.
48. Rubus hispidus, L. Running Swamp Blackberry. Common on the sand dunes.
49. Rubus Canadensis, L. Running Blackberry. Dewberry. Rocky places.
50. Fragaria Virginiana, Mill. Strawberry. Common.
51. Fragaria vesca, L. Strawberry. Woods common.
52. Potentilla Norvegica, L. Port Austin.
53. Potentilla argentea, L. Silvery Cinquefoil. Roadsides.
54. Potentilla Anserina, L. In an abandoned quarry near the lake at Grindstone City. Also near the lake at Sand Beach. Bayport.
55. Potentilla palustris, Scop. Marsh Five-Finger. In a bog on Sec. 11, Chandler township.
56. Rosa blanda, Aiton, Sweet Wild Rose. Growing in the sand and nearly buried in it at Hat Point.
57. Rosa Carolina, L. Swamp Rose. Swamps. Common.
58. Rosa rubiginosa, L. Sweet-brier. Roadside near Port Austin.
59. Pyrus arbutifolia, L. f. var. melanocarpa, Hook. Choke-cherry. Abundant on N. Charity Island.
60. Cratægus punctata, Jacq. Thorn-apple. Hawthorn. Dry fields and woods, Port Austin.
61. Amelanchier Canadensis, Torr. and Gray. Shad-bush. June-berry. Service-berry. Stream banks.
62. Amelanchier Canadensis, Torr. and Gray. Var. rotundifolia, T. & G. Sand dunes.
63. Amelanchier Canadensis, Torr. and Gray. Var. (?) oblongifolia, T. & G. Common on sand dunes.
64. Ribes Cynosbati, L. Prickly Gooseberry. Dry open ground along the lake. Port Austin.
65. Myriophyllum heterophyllum, Michx. Pinnebog River, Port Crescent.
66. Callitriche verna, L. Water Starwort. Dry bed of branch of Pinnebog River, Hume Township.
67. Epilobium spicatum, Lam. Great Willow-herb. Fire weed. Common on all sandy land following fires.
68. Epilobium lineare, Muhl. Bog in Chandler Township.
69. Epilobium coloratum, Muhl. Port Austin.
70. Œnothera biennis, L. Evening Primrose. Common.
71. Circæa lutetiana, L. Common in woods.
72. Circæa alpena, L. Common in low woods.
73. Pimpinella integerrima, Benth and Hook. Dry rocky soil. Port Austin Township.
74. Cicuta maculata, L. Spotted Cowbane. Beaver Poison. Musquash Root. Low grounds, common. Tuberous roots very poisonous.
75. Cicuta bulbifera, L. Bog in Chandler Township.
76. Hydrocotyle Americana, L. Water Pennywort. Moist woods, Port Austin.
77. Aralia racemosa, L. Spikenard. Rich woods, Dwight Township.
78. Aralia hispida, Ventenat. Bristly Sarsaparilla. Wild Elder. Sand dunes. Port Austin.
79. Aralia nudicaulis, L. Wild Sarsaparilla. Rich woods. Meade Township.
80. Aralia trifolia, Decsne & Planch. Groundnut. Dwarf Ginseng.
81. Cornus Canadensis, L. Bunch-berry. Most woods near Port Austin.
82. Cornus circinata, L'Her. Round-leaved Dogwood. Lake shore at Hat Point.
83. Cornus stolonifera, Michx. Red-osier Dogwood. Low ground along streams. Port Austin.
84. Cornus Baileyi, Coulter & Evans. Very common along the lake on sand dunes. Also at Bay Port.
85. Cornus alternifolia, L. f. Near Port Austin, in rich woods.
86. Sambucus Canadensis, L. Common Elder. Roadsides.
87. Sambucus racemosa, L. Red Berried Elder. Dry woods.
88. Viburnum acerifolium, L. Arrow wood. Woods, frequent about Port Austin.
89. Cephalanthus occidentalis, L. Button-bush. Found growing just back of the beach a short distance west of Port Austin, in comparatively dry, light soil. Inland in river bottoms, etc.
90. Galium pilosum, Ait. Sand dunes east of Port Austin.

91. Galium circæzans, Michx. Wild Liquorice. Dry woods.
92. Galium boreale, L. Northern bedstraw. At Point aux Barques.
93. Eupatorium purpureum, L. Joe Pye weed. Trumpet Weed. Along streams and swamps, common.
94. Eupatorium perfoliatum, L. Thoroughwort. Boneset. Low grounds. Common.
95. Eupatorium ageratoides, L. White snake-root. Valley of the Pinnebog River, west of Port Crescent.
96. Liatris cylindracea, Michx. Blazing Star. Sand dunes. West of Port Crescent where it is common.
97. Solidago cæsia, L. Golden-rod. Common.
98. Solidago latifolia, L. Golden-rod. Rich woods in central part of county.
99. Solidago bicolor, L. Var. concolor. Torr. & Gray. Sand dunes.
100. Solidago juncea, Ait. Dry fields and pastures near Port Austin.
101. Solidago serotina, Ait. Low grounds, borders of woods in center of county. Port Austin.
102. Solidago Canadensis, L. Borders of fields, etc., common.
103. Solidago nemoralis, Ait. Sand dunes west of Port Crescent.
104. Aster macrophyllus, L. Wild aster. Dry woods. Common.
105. Aster Novæ-Angliæ, L. A single plant found on north Charity Island. (Common along Saginaw River in Saginaw and Bay counties.)
106. Aster lævis, L. Along the older sand dunes.
107. Aster junceus, Ait. Bog on North Charity Island.
108. Aster puniceus, L. Low grounds throughout the county.
109. Erigeron Canadensis, L. Horse weed. Bitter weed. Waste places and cultivated ground.
110. Erigeron strigosus, Muhl. Daisy Fleabane. Port Austin.
111. Erigeron Philadelphicus, L. Common Fleabane. Common about Port Austin.
112. Ambrosia Artemisiæfolia, L. Ragweed. Roman wormwood. Waste places and roadsides.
113. Xanthium Canadense, Mill. Cocklebur. Clotbur. Along streams and ditches.
114. Rudbeckia hirta, L. Cone-flower. Fields, not common, about Port Austin.
115. Anthemis Cotula, DC. May-weed. Dog-fennel. Roadsides and waste places.
116. Achillea Millefolium, L. Yarrow. Grassy places, common.
117. Chrysanthemum Balsamita, L. Var. tanacetoides. Boiss. Mint Geranium. By the roadside near Port Austin.
118. Tanacetum vulgare, L. Common tansy. Growing in drifting sand near Port Crescent, also by the roadside at other points.
119. Artemisia caudata, Michx. Common on the sand dunes along the lake.
120. Artemisia Absinthium, L. Common wormwood. Roadside near Port Austin.
121. Artemisia Stelleriana, Bess. This plant is well established in the sand of a roadside dune between Port Austin and Port Crescent where it covers a large space. It is also abundant in the barren sand near Huron City, and a large tuft of the plant grows in the sand just back of the storm wave line near the old Carrington Salt Blocks at Port Austin. Prof. Wheeler of the Agricultural College informs the writer that it has not been previously reported as growing wild in the state.
122. Erechtites hieracifolia, Raf. Fireweed. Common in clearings and burned places in the woods.
123. Arctium Lappa, L. Burdock. Waste places, Port Austin.
124. Cnicus lanceolatus, Hoffm. Common thistle. Roadside and pastures.
125. Cnicus Pitcheri, Torr. Shore of the Lake, near Hat Point. Abundant at North Charity Island, not seen back of the crest on the first dune line.
126. Cnicus arvensis, Hoffm. Canada thistle. The northern part of the county is very badly infected with this pest, which seems to have taken possession of many fields and a large number of grain fields seemed to show more thistles than grain. The Canada Thistle Law should be enforced here.
127. Hieracium Canadense, Michx. Hawkweed. Shaded banks about Port Austin.
128. Hieracium venosum, L. Rattle snake weed. Sand dunes from Port Austin westward.
129. Lobelia cardinalis, L. Cardinal Flower. River banks and streams.
130. Campanula rotundifolia, L. Harebell. Rocks and dunes near Port Austin.
131. Campanula aparinoides, Pursh. Marsh Bellflower. Common in grassy swamps.
132. Gaylussacia resinosa, Torr. and Gray. Black Huckleberry. Along woods. Very common on the sand dunes.
133. Vaccinium Pennsylvanicum, Lam. Huckleberry. Low Blueberry. Abundant on the sand dunes and in dry soil generally.
134. Vaccinium vacillans, Solander. Low Blueberry. Sand dunes west of Port Crescent.
135. Vaccinium Corymbosum, L. Swamp or High bush Blueberry. Swamp and marshes about Rush Lake.
136. Vaccinium macrocarpon, Ait. Cranberry. Near Hat Point, and at North Charity Island.
137. Arctostaphylos Uva-ursi, Spreng. Bearberry. On the sand dunes west of Port Crescent.
138. Epigæa repens, L. Trailing Arbutus. Sand dunes under pines near Port Austin.
140. Cassandra calyculata, Dan. Leather-Leaf. Bog in Chandler Township.
141. Chimaphila umbellata, Nutt. Pipsissewa. Prince's Pine. Port Austin near Broken Rocks.
142. Pyrola elliptica, Nutt. Shin-leaf. Pine woods. Port Austin.
143. Trientalis Americana, Pursh. Star-flower. Rich woods near Port Austin.
144. Steironema ciliatum, Raf. Low grounds along streams. S.

145. Samolus Valerandi, L. Var. Americanus. Gray. Water Pimpernel. Brook weed. Bank of Pinnebog River. Hume Township.
146. Fraxinus sambucifolia, Lam. Black Ash. Swamps in central part of county.
147. Apocynum androsæmifolium, L. Spreading Dogbane. Near Port Austin.
148. Apocynum cannabinum, L. Indian Hemp. Stream banks near Port Austin.
149. Asclepias tuberosa, L. Butter-fly weed. Pleurisy-root. Sand dunes near Port Austin.
150. Asclepias incarnata, L. Swamp milkweed. Swampy margins of streams.
151. Asclepias Cornuti, Decaisne. Common milkweed or silkweed. Roadsides and fields. Grows in bare sand in some places and serves to help keep it from drifting.
152. Menyanthes trifoliata, L. Buckbean. Bog in Chandler Township.
153. Cynoglossum officinale, L. Hound's-tongue. Roadsides near Port Austin.
154. Echinospermum Lappula, Lehm. Waste places. Port Austin.
155. Lithospermum hirtum, Lehm. Puccoon. Sand dunes near Port Austin.
156. Convolvulus sepium, L. Hedge. Bind weed. Wild Morning Glory. Low grounds along the Pinnebog River. Hume Township.
157. Cuscuta Gronovii, Willd. Dodder. Parasite on various plants, valley of the Pinnebog River.
158. Solanum nigrum, L. Common Nightshade. Waste places, Port Austin.
159. Verbascum Thapsus, L. Mullein. Sterile soil, especially where fire has burned the other vegetation off within a few years.
160. Linaria Canadensis, Dumont. Sand dunes west of Port Crescent.
161. Linaria vulgaris, Mill. Butter and Eggs. Roadside, Bay Port.
162. Chelone glabra, L. Snake head. Banks of streams.
163. Mimulus ringens, L. Monkey-flower. Damp, open ground about Port Austin.
164. Veronica Americana, Schweinitz. American Brooklime. Brooks near Port Austin.
165. Gerardia pedicularia, L. Dry, sandy woods. North Charity Island.
166. Gerardia quercifolia, Pursh, Smooth False Foxglove. Dry sandy woods, North Charity Island.
167. Gerardia purpurea, L. Var. paupercula, Gray. Purple Gerardia. Very common on the shore near the hotel, Bayport. Also at Charity Island.
168. Utricularia intermedia, Hayne. Holes in the bog, Chandler Township.
169. Utricularia cornuta, Michx. Bladderwort. In shallow pool left by the retreat of the lake, on the beach just east of Port Austin. A small flowered stunted form of the species, common at Bayport on the flats along the Bay shore.
170. Verbena urticæfolia, L. White Vervain. Port Austin.
171. Verbena hastata, L. Blue Vervain. Low grounds, common.
172. Mentha piperita, L. Peppermint. Roadside near Port Austin.
173. Mentha Canadensis, L. Wild Mint. Low grounds and along streams.
174. Calamintha clinopodium, Benth. Basil. Dry banks and dunes about Port Austin.
175. Monarda fistulosa, L. Wild Bergamot. Sandy fields near the dunes. Port Austin.
176. Nepeta Cataria, L. Catnip. Waste places. Port Austin.
177. Scutellaria lateriflora, L. Low grounds. Pinnebog River, etc.
178. Scutellaria galericulata, L. Skullcap. Bog in Chandler Township.
179. Marrubium vulgare, L. Horehound. Roadside near Port Austin.
180. Leonurus Cardiaca, L. Motherwort. Waste places. Port Austin.
181. Brunella vulgaris, L. Self-heal. Woods and thickets.
182. Amarantus albus, L. Tumble weed. Growing in the sand at Port Austin and Port Crescent.
183. Chenopodium Botrys, L. Jerusalem Oak. Feather. Geranium. Ambrosia. Growing abundantly in the dune sand at Port Austin and about the old salt block at Port Crescent.
184. Chenopodium album, L. Pigweed. Common in waste places and cultivated ground.
185. Chenopodium capitatum, Watson. Strawberry Blite. Occasional in woods.
186. Rumex crispus, L. Curled Dock. Yellow Dock. Too common.
187. Rumex obtusifolius, L. Bitter Dock. Common in waste places.
188. Rumex Acetosella, L. Field or sheep sorrel. Common.
189. Polygonum aviculare, L. Knotweet. Common.
190. Polygonum erectum, L. Common along roadsides.
191. Polygonum orientale, L. Prince's Feather. Port Austin.
192. Polygonum Persicaria, L. Lady's Thumb. Gull Island, Lake Huron. Also in wet places.
193. Polygonum cilinode, Michx. Bindweed. Waste heaps about the quarries at Grindstone City. Rocky places west of Port Austin.
194. Polygonella articulata, Meisn. Abundant on the outer row of sand dunes.
195 Saururus cernuus, L. Lizard's-tail. Pinnebog River. Hume Township.
196. Shepherdia Canadensis, Nutt. Point Aux Barques on sandstone rocks overhanging the lake. Also on sand dunes west of Port Crescent.
197. Comandra umbellata, Nutt. Dry woods near Port Austin.
198. Euphorbia Cyparissias, L. At Bayport, where it covers considerable area. Also at Port Austin and Huron City in sand.
199. Ulmus Americana, L. White, or American Elm. Low grounds, common.
200. Humulus Lupulus, L. Common Hop. Near Port Austin.
201. Betula lutea, Michx. f. Yellow Birch. Common in low woods.
202. Betula papyrifera, Marshall. Paper or Canoe Birch. White Birch. Common
203. Alnus incana, Willd. Speckled or Hoary Alder. Borders of streams.
204. Quercus alba, L. White Oak. Sand dunes at Port Austin.

205. Quercus rubra, L. Red Oak. Common on the sand dunes, where it is sometimes a large tree, but not usually. Evidently the large specimens have been cut for timber.
206. Quercus coccinea, Wang. Scarlet Oak. The most abundant species of oak in the dunes.
207. Fagus ferruginea, Ait. Beech. Common throughout the county on heavier soils.

Salix. Several species of Willows are common but were not found in favorable condition for study.

208. Populus alba, L. White Poplar. Port Austin.
209. Populus tremuloides, Michx. American Aspen. Quaking asp. Common in the east half of the county.
210. Populus grandidentata, Michx. Large-toothed Aspen. Common.
211. Populus balsamifera, L. Balsam Poplar. Perhaps the most abundant species in the districts most affected by the great fires.
212. Populus monilifera, Ait. Cottonwood. Occasional.
213. Vallisneria spiralis, Tape Grass. Eel Grass. Mouths of Pinnebog and Pigeon Rivers.
214. Calopogon pulchellus, R. Br. Marsh at Rush Lake.
215. Iris versicolor, L. Blue Flag. Low grounds. Common.
216. Smilax hispida, Muhl. Port Austin.
217. Smilacina stellata, Desf. False Solomon's Seal. Common on sand dunes west of Port Crescent.
218. Juncus effusus, L. Soft Rush. Common in low ground.
219. Juncus Balticus, Dethard. Var. littoralis, Engelm. Very common in the beach sand at Port Austin where it forms large masses in the sand for several hundred feet back from the shore, especially up the creek valley.
220. Juncus bufonius, L. Forming extensive tracts on the marshy area left by the fall of the waters of the lake during the past few years.
221. Juncus alpinus, Villars, Var. insignis, Fries. Abundant in the creek valley at Port Austin, also not uncommon along the Lake shore.
222. Juncus nodosus, L. Common with the last species.
223. Juncus Canadensis, J. Gay. Same habitat as the last species.
224. Juncus Canadensis, J. Gay. Var.. coarctatus Engelm. Port Austin.
225. Juncus Canadensis, J. Gay. Var. brachycephalus, Engelm. Port Austin.
226. Luzula vernalis, DC. Wood-rush. Common in moist woods.
227. Typha latifolia, L. Cat-tail Flag. Rush Lake. Marsh in Chandler Township.
228. Sparganium eurycarpum, Engelm. Burr-reed. Pinnebog River.
229. Alisma Plantago, L. Water Plantain. Common in streams.
230. Sagittaria variabilis, Engelm. Stream borders.
231. Triglochin palustre, L. Arrow-Grass. Marshy border of Lake Huron. Port Austin.
232. Potamogeton natans, L. Pondweed. Terrestrial forms of this species noted on shore of partly dried up lake in Chandler Township and in bottom of dried up pond on Charity Island.
233. Potamogeton heterophyllus, Schreb. Small form in shallow pools above low water mark, on beach east of Port Huron.
234. Potamogeton heterophyllus, Schreb. Forma longipedunculatus (Merat) Morong. This form was collected in water nearly four feet deep off the beach at Point of Pines Hotel, Port Austin. The root stocks of the plants grow in crevices in the rocks, and the plants thrive in spite of the violent surf which frequently breaks on this shore.
235. Potamogeton pauciflorus, Pursh. Var. Niagarensis, Gray. Pinnebog River.
236. Potamogeton pectinatus, L. Pigeon River, Caseville.
237. Potamogeton marinus, L. Shallow water, less than one foot deep on beach between Port Austin and Port Crescent. Also at North Charity Island in water six inches deep, abundant at both localities.
238. Naias flexilis, Rostk and Schmidt. Willow River, Huron Township.
239. Cyperus diandrus, Torr. Var. castaneus, Torr. Very common along the lake shore, and along margins of streams.
240. Cyperus Houghtonii, Torr. Abundant on the sand dunes west of Port Crescent, where it grows in the purest sand, often in the wagon tracks across the dunes.
241. Cyperus strigosus, L. Common in marshy places along the lake at Port Austin.
242. Dulichium spathaceum, Pers. Rush Lake.
243. Eleocharis ovata, R. Br. Common along the shore of the lake.
244. Eleocharis olivacea, Torr. Lake shore.
245. Eleocharis palustris, R. Br. Var. glaucescens, Gray. Common in wet places.
246. Eleocharis acicularis, R. Br. Spike-rush. Very abundant along the lake shore.
247. Eleocharis pauciflora, Link. Forming large masses on the marshy belt left by the retreat of the lake near Port Austin. Bayport.
248. Scirpus pungens, Vahl. Growing in moist sand for several hundred feet away from water at Port Austin Harbor. Bayport.
249. Scirpus lacustris, L. Common, especially at Rush Lake, where it forms large masses.
250. Scirpus atrovirens, Muhl. Damp soil, common. Very abundant near the R. R. station, Port Austin. Bayport.
251. Cladium mariscoides, Torr. Twig-rush. Marsh about pond on North Charity Island.
252. Carex lupulina, Muhl. Common along ditches, etc.

253. Carex filiformis, L. Bog in Chandler Township.
254. Carex flava, L. Var. viridula, Bailey. Abundant at Bayport and Charity Islands in the marshy tract left by retreat of lake. Less common at Port Austin. At North Charity Island, some plants were 18 inches high.
255. Carex riparia, W. Curtis. River banks.
256. Carex eburnea, Boott. Crevices in sandstone bluff overhanging the lake.
257. Carex Pennsylvanica, Lam. Common throughout.
258. Carex communis, Bailey. Port Austin Township, near Grindstone City.
259. Carex stipata, Muhl. Common in low places.
260. Carex vulpinoidea, Michx. Meadows, common.
261. Carex Muhlenbergii, Schb. Dry soil on the bluffs. Point aux Barques.
262. Carex tribuloides, Wahl. Common in low grounds.
263. Carex tribuloides, Wahl. var. cristata, Bailey. Swales, common.
265. Spartina cynosuroides, Willd. Marsh or cord grass. Sand dunes.
266. Panicum sanguinale, L. Crab or Finger Grass. At Port Crescent in drifting sand where it was getting a foothold and may help hold the sand in place.
267. Panicum virgatum, L. Charity Islands on sand soil.
268. Panicum capillare, L. Old Witch-Grass. Common.
269. Panicum dichotomum, L. Sand dunes west of Port Crescent.
270. Setaria viridis, Beauv. Green Foxtail. In loose sand at Port Crescent, with Panicum sanguinale.
271. Zizania aquatica, L. Indian Rice. Water oats. Wild rice. Marshy places along the lake shore, usually small in such locations. Off Bayport, however, it grows in shallow water to the height of several feet, covering large tracts, and undoubtedly acting as an important factor in the filling up of the portions of the Bay in which it grows, by decreasing wave and current motion of the water, hence hastening deposit.
272. Andropogon furcatus, Muhl. North Charity Island.
273. Oryzopsis asperifolia, Michx. Sides of older dunes about Port Austin.
274. Oryzopsis Canadensis, Torr. Sand dunes, where it is common.
275. Phleum pratense, L. Timothy. Herd's Grass, common. Extensive crops of this grass may be raised in the swampy tracts south and east of Badaxe when they are cleared and drained.
276. Agrostis scabra, Willd. Hair-grass. Dry pastures in Huron Township.
277. Calamagrostis longifolia, Hook. Sand dunes about Port Austin.
278. Ammophila Arundinacea, Host. Sand dunes nearest lake. Common.
279. Deschampsia flexuosa, Trin. Common Hair-Grass. Abundant in the dunes of Port Austin.
280. Phragmites Communis, Trin. Reed. Border of dry pond in Charity Island.
281. Danthonia spicata, Beauv. Wild Oat-Grass. Sand dunes, common.
282. Koeleria cristata, Pers. Slopes of the older sand dunes.
283. Eragrostis reptans, Nees. Along the lake shore and borders of streams.
284. Poa compressa, L. Wire-Grass. Blue-Grass. The top of the bluffs at Point aux Barques.
285. Poa pratensis, L. June Grass. With the last and common everywhere.
284. Festuca tenella, Willd. Common on sand dunes and on the dry soil at Broken Rocks, Port Austin.
287. Festuca ovina, L. Var. pseudovina, Hack. Broken Rocks near Port Austin. ?
288. Agropyrum dasystachyum, Vasey. Common on the sand dunes.
289. Elymus Virginicus, L. Wild Rye. Valley of Pinnebog River, Hume Township.
290. Elymus Canadensis, L. Growing on the sand dunes nearest the lake at Port Austin. Abundant.
291. Asprella Hystrix, Willd. Bottle Brush Grass. Woods near Port Austin.
292. Pinus Strobus, L. White Pine. Formerly very abundant throughout a large portion of the county, mostly confined in the dunes near the lake.
293. Pinus Banksiana, Lambert. Jack Pine. Scrub Pine. Common on the sand dunes. Not seen east of Broken Rocks, Port Austin. West of Port Crescent it is common even on the crest of the dune line nearest the lake.
294. Pinus resinosa, Ait. Norway Pine. Red Pine. Common on the sand dunes.
295. Picea nigra, Link. Black Spruce. In low woods west of Filion.
296. Larix Americana, Michx. Black Larch. Tamarack. Swamps in the southern part of the county.
297. Tsuga Canadensis, Carriere. Hemlock. Banks of Willow River in Huron Township.
298. Abies balsamea, Miller. Balsam fir. Balm-of-Gilead Fir. A few specimens about a boggy place on the dunes east of Port Crescent. Swamp just west of Port Austin.
299. Thuya occidentalis, L. Arbor Vitæ. White Cedar. Wet places near Port Crescent.
300. Equisetum arvense, L. Horsetail. Low grounds, common.
301. Equisetum hyemale, L. Scouring-Rush. Shave-Grass. Sand dunes east of Port Austin.
302. Equisetum variegatum, Schleicher. What seems to be this species was not uncommon in the sand near Port Austin.
303. Polypodium vulgare, L. Under overhanging rocks along the Lake shore, Point aux Barques, etc.
304. Adiantum pedatum, L. Maidenhair fern. Rich woods.
305. Pteris aquilina, L. Common brake. Very common in northern part of county.
306. Phegopteris polypodioides, Fée. Under overhanging rocks of old shore cliff, east of Point aux Barques.
307. Phegopteris Dryopteris, Fée. With the last species.
308. Onoclea sensibilis, L. Sensitive fern.Common in low grounds.

309. Osmunda regalis, L. Flowering Fern. Deep woods in the middle of the county.

310. Woodsia obtusa, Torr. Growing abundantly in crevices in the overhanging rocks on the Lake shore near Port Austin.

311. Lycopodium complanatum, L. Var. Chamæcyparissus, D. C. Eaton. Common on the sand dunes, east of Port Crescent.

312. Selaginella apus, Spreng. In old quarry at Grindstone City.

A visit of a day's duration to Bayport in July, 1898, indicates that the flora of that part of the county is especially interesting to botanists, as a number of species of plants were found there which have not before been found so far north in Michigan and some reach their most northern recorded limit here.

14a. *Hypericum Kalmianum, L. St. John's-wort. Marshy land south of Bayport.

30a. Medicago sativa, L. Alfalfa, Lucerne. Along the line of the sewer from the Bayport Hotel to the Bay.

66a. Lythrum alatum, Pursh. Purple Loose-strife. Marshy borders of ditches, between Sebewaing and Bayport.

96a. Liatris spicata, Willd. Blazing-star. Marshes north of Sebewaing.

103a. Solidago Ohioensis, Riddell. Golden-rod. Marsh near Bayport.

111a. Silphium terebinthinaceum, L. Prairie Dock. Along the S. T. & H. R. R. nearly as far north as Bayport.

121a. Cacalia tuberosa, Nutt. Tuberous Indian Plantain. North of Sebewaing nearly to Bayport, in rich soil.

128a. Lactuca scariola, L. Prickly lettuce. A bad weed common about the railroad stations.

129a. Lobelia Kalmii, L. Wet flats along the shore of the Bay at Bayport.

144a. Steironema longifolium, Gray. Marshes south of Bayport.

181a. Plantago Patagonica, Jacq. Var. aristata, Gray. Bristly Plantain. Grounds of the Bayport Hotel under trees, sandy soil.

207a. Salix amygdaloides, Anders. Bayport.

213a. Spiranthes cernua, Richard. What seems to be this species was collected by Dr. Lane in the neighborhood of Bayport.

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*These numbers refer to the place which these plants would occupy if arranged in the foregoing list.

CHAPTER X

THE FOSSILS.

§ 1. Introduction.

When we attempt to study and name the forms of life which have left their traces in the rocks of Huron county we find ourselves in much difficulty. The earlier papers on the subject by Winchell, Strong and Stevens, were published without illustrations. All the illustrations that Douglas Houghton prepared seem to have disappeared. At the Ann Arbor Museum and Grand Rapids High Schools, however, are numerous forms labelled, so that after diligent study by one who has access to the complete literature of other states (especially whenever Winchell's unpublished drawings become accessible), we shall know better just what forms have been named by the gentlemen above, and how far they are equivalent to forms described in other states. In the meantime geologists in other states have worked perforce without very much regard to what had been done in Michigan, though Herrick and others have occasionally referred to Winchell's types. The material is in large part so imperfect that Winchell has in a number of cases referred a form now to one genus and now under another, retaining the same specific name. Rominger, too, collected extensively in the county, but his identifications are generally not specific and by no means always harmonize with those of previous authors. In consequence the following cases of difficulty arise:

We may be almost certain that a form has been given a certain specific name by a previous author, but doubt if his reference of it to a certain genus is correct; or we may not be certain whether we have the exact form described by a certain author. Or we may find the same form referred to by different authors under different names. In some cases we know that this is so, as when Hall uses Winchell's figures of *Centronella Julia* to illustrate *Cryptonella*. The same form is now known as *Romingerina.*

The snarl thus involved can not be straightened out at once. But we can at least take out some kinks, and make it easier for the next one, and at the same time give lists which show what names have been applied to the fossils of the county.

We treat the fossils of the Marshall and underlying shales together, for even if we did not wish to imply thereby very much, as to the controverted question of their relation to the line between Devonian and Carboniferous, since the literature is the same, and we shall have occasion to compare the forms, it seems better to treat them thus.

We have illustrated part of the Marshall fauna in Plates X and XI, but have not tried to do so for the faunas of the Bayport, i. e., Maxville limestone, reserving that for a Kent county report when the collections of the Kent Scientific institute shall be accessible, and shall have been properly worked up.

It is impossible, too, to do complete justice to the Marshall fossils until Winchell's collection is also accessible to the investigator, which we trust will be soon, now that it is acquired by the Francis Hood Museum of Alma College. But I am particularly indebted to Mr. W. F. Cooper who is familiar with Mr. Herrick's parallel work in Ohio for his assistance in that section. Most of the forms illustrated in Plates X and XI are not Marshall, but come from the Point aux Barques lighthouse. I hope to illustrate the Marshall more fully later from Winchell's own drawings but most of his specimens came from the southern part of the state.

§ 2. Recent shells (of the marl), by Bryant Walker and A. C. Lane.

It has been suggested by certain recent observers* that the former extension of the Great Lakes so well marked in raised beaches around the lower peninsula of Michigan, were really connected with the ocean and their deposits of marine origin, and for this and other reasons, during the progress of the investigations of the Geological Survey, in Huron county, last summer, some attempt was made by Prof. Davis and Mr. Lane to gather shells from recent deposits, where they would be likely to throw light upon the subject. These shells have been referred to Mr. Bryant Walker and the Pisidia to Dr. V. Sterki to whom all that is valuable of this paper should be attributed. All that Mr. Lane adds is something concerning the localities.

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*Spencer, J. W., Science, 1888, Jan. 27, p. 49, Pop. Sci. Monthly, 1896. Bela Hubbard, back in 1840, correctly described them as fresh water deposits.

Locality (1).—Near Badaxe, about one-fourth mile N. of the southeast corner of Sec. 24, T. 16, R. 12; altitude about 180 feet above the present lake level, or say 760 feet A. T. Here the E.—W. drain exposes a section showing an alternation of above a marshy deposit, then a shell marl, then another marshy deposit, then a second bed of shell marl. Mr. Lane's attention was called to the alternation by Dr. Jas. Henderson. At the time it was visited, the section was exposed by a ditch which was so filled with water that a careful separation could not be made of the two marls, but without doubt, the forms were very largely derived from the lower marl. It seems geologically very likely that the lower marl is associated in this region with, and nearly contemporaneous with, the Forest Beach of Lake Warren.* A collection was made from a marl at a similar altitude and in association with marshes also behind the Forest Beach on Sec. 6, Sherman, T. 15 N., R. 16 E., in 1897. The fauna was similar and ***Pisidium contortum*** occurred again.

Locality (2).—Close to the Stone Wall also referred to by Taylor (loc. cit., page 44), in the swamp in which the Stone Wall is connected and at a similar elevation. This is in the southeast corner of Sec. 32, T. 14 N., R. 11 E. This, too, is very possibly to be correlated with the time of the Forest Beach and Lake Warren,—according to Taylor this marsh lies in the Cumber spillway, a channel by which the waters on the two sides of the thumb were connected when the ice front was standing near Verona.

This locality is more fully described in Part III of this volume.

Locality (3).—Sand which was exposed in burning off the bog near the corner of Secs. 26 and 27, T. 16 N., R. 9 E. Fairhaven township, Huron county, Michigan. These sands lie at an elevation of a little above 20 feet (605 ft. A. T.). They are to be connected with the Algonquin Beach, according to Taylor. They certainly are connected with the old lake shore directly in a way that the two marl deposits just mentioned are not.

Locality (4).—On the north side of Sec. 34, T. 16 N., R. 9 E., about ¼ mile E. of the N. W. quarter where the section line road crosses the dunes. They are connected with the same Algonquin lake level as the previous locality, though somewhat higher, and are evidently fragments thrown up on the beach directly connected with the dune deposits.

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*See F. B. Taylor, Bull. Geol. Society of America, Vol. VIII, p. 49.

Finally collections were also made of recent forms for comparison.

Locality (5).—Living forms collected by C. A. Davis at Port Austin.

Locality (6).—Living forms collected by Mrs. A. C. Lane, in flats laid bare by the recent fall of the waters in front of Bayport during the last eight years. It will be seen from the lists that with two exceptions, all the species found are identical with forms now existing in the same region. Such variations as now exist are no more than can be attributed to local peculiarities of environment. The fauna of the older marls as a whole is undoubtedly a northern one, and indicates, though not necessarily conclusively, a colder climate than exists in that region today. This inference is based on the uniformly small size of the same species, i. e., *Valvata tricarinata, Planorbis deflectus, Planorbis bicarinatus* and the Campeloma, also the peculiar sculpturing of the *Planorbis bicarinatus.*

The single example of Campeloma is a very interesting one, though it is unfortunately very imperfect. It is apparently mature, and is remarkable for its small size and cylindrical shape. It also resembles the northern recent form known as *Campeloma milesii* Lea, but is smaller and more cylindrical. If the form of the living species is the result of its northern situation, it would perhaps be a fair inference that severer climatic conditions had so to speak intensified the form. However, while *C. milesii* is today a northern form, there are other species of the same genus ranging from the same territory, as well as further north, which do not show the same peculiarity. Then there is a little *Limnœa* from Badaxe, locality (1), which is also interesting. It resembles the species from the Moose River, in the Hudson Bay territory, described by Lea as *L. artica*, but differs in its compressed shape and in being decidedly umbilicate.

In regard to the *Pisidia* in particular, Dr. V. Sterki, who examined the material, says that the Badaxe specimens are of especial interest and correspond with those from the marl in Aroostook county, Maine. There is in both *Pisidium contortum* Pme., a form which has been referred to or near *Pisidium milium* Held, from Europe, and certainly is nearly related, but the species is very variable. The extreme forms might be regarded as quite distinct species, but for intermediate forms. *Pisidium contortum* is known only as fossil, but may yet be found living further north.[*] *P. ventricosum* Pme. so common in the Maine marl was not represented in the Michigan material. In the Fairhaven material location (3) or (4) were a few broken fossils, one of them to be identified as *Pisidium contortum*, the balance too far gone.

It is obvious from the comparison of these lists appended and observations made upon them that so far the shell collections point, not to marine conditions, but to fresh water conditions something similar to those present, but to a more northern climate, which is in every way agreeable to the other geological indications, that their erstwhile denizens dwelt in lakes left upon the retreat of the ice, the shells from localities (1) and (2) being probably more nearly contemporaneous with the ice front and with the mastodon.[†]

In the list, the names of the genus, species and describer are first given, in order, grouped by genera, and then in the seven following columns, their occurrence in Walker's list of shells of the Saginaw valley[‡] and in the six localities above mentioned. An X indicates the presence of form, XX its abundance, a number added refers to foot note.

? indicates that the specimen is too imperfect for certain identification.

Genus.	Species.	Author.	Walker's list.	Loc. 6.	5.	4.	3.	2.	1.
Circinaria	*concava*	Say	x	......	......	......	......	......	......
Zonitoides	*nitidus*	Mull	x	......	......	......	......	......	......
"	*arboreus*	Say	x	......	......	......	......	x	......
"	*minusculus*	Alder	x	......	......	......	......	......	......
Vitrea	*hammonis*	Ström	x	......	......	......	......	......	......
"	*indentatus*	Binn	x	......	......	......	......	......	......
Conulus	*fulvus*	Dr	x	......	......	......	......	......	......
Gastrodonta	*multidentata*	Say	x	......	......	......	......	......	......
Pyramidula	*alternata*	Say	x	......	......	......	......	......	......
"	*perspectiva*	Say	x	......	......	......	......	......	......
"	*striatella*	Anth	x	......	......	......	......	......	......
Helicodiscus	*lineatus*	Say	x	......	......	......	......	......	......
Punctum	*pygmaeum*	Drap	x	......	......	......	......	......	......
Polygra	*multilineata*	Say	x	......	......	......	......	......	......
"	*thyroides*	Say	x	......	......	......	......	......	......
"	*albolabris*	Say	x	......	......	......	......	......	......
"	*albolabris dentata*	Tryon	x	......	......	......	......	......	......
"	*exoleta*	Binn	x	......	......	......	......	......	......
"	*sayii*	Binn	x	......	......	......	......	......	......
"	*monodon fraterna*	Say	x	......	......	......	......	......	......
"	*leaii*	Ward	x	......	......	......	......	......	......
"	*tridentata*	Say	x	......	......	......	......	......	......
"	*palliata*	Say	x	......	......	......	......	......	......
"	*virgata*	DaCosta	x	......	......	......	......	......	......
Vallonia	*pulchella*	Mull	x	......	......	......	......	......	......
Strobilops	*labyrinthica*	Say	x	......	......	......	......	......	......
Bifidaria	*corticaria*	Say	x	......	......	......	......	......	......

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[*] It has recently been found living in northern Maine.

[†] See articles by B. Walker in the Nautilus March, 1898, Vol. XI, p. 121, and Sept., 1899, Vol. XIII, p. 55.

[‡] Nautilus, 1894, p. 125.

Genus.	Species.	Author.	Walkers list.	Loc. 6	5	4	3	2	1
Bifidaria	*armifera*	Say.	x						
"	*contracta*	Say.	x						
"	*pentodon*	Say.	x						
"	*curvidens*	Gld.	x						
Vertigo	*ovata*	Say	x						
"	*gouldii*	Binn	x						
"	*ventricosa elatior*	Sterki	x						
Cochlicopa	*lubrica*	Mull	x						
Succinea	*ovalis*	Say.	x						
"	*avara*	Say.	x						
"	*retusa*	Lea.	x		x				
"	*peoriensis*	Wolf.	x						
"	*sp*		x						
"	*sp*		x						
Carychium	*exiguum*	Say.	x						
Limnæa	*stagnalis*	L.	x		x				
"	*catascopium*	Say.	x	x	x				
"	*reflexa*	Say.	x		x				
"	*reflexa scalaris*	Walker.	x						
"	*palustris*	Mull	x		x				
"	n. sp								x(1)
"	*cubensis*	Pfr.	x						
"	*desidiosa*	Say.			x			xx	x
"	*emarginata*	Say.			x				
Physa	*ancillaria*	Say.	x		x			x	
"	*sayii*	Tappan.	x	x					
"	*gyrina*	Say.			x			x	
"	" *var. hildrethiana*	Lea.	x						
Aplexa	*hypnorum*	L.	x						
Planorbis	*trivolvis*	Say.	x						
"	*multivolvis*	Case.	x		x				
"	*bicarinatus*	Say.					x	xx	xx(2)
"	*truncatus*	Miles.		x	x				
"	*deflectus*	Say.					x	xx	xx
"	*campanulatus*	Say.	x				x	x	xx
"	*albus*	Mull	x						
"	*parvus*	Say.	x		x				
"	*exacutus*	Say.	x						
Segmentina	*armigera*	Say.	x		x				
Ancylus	*fuscus*	Ad.							
"	*sp*								?
"	*parallelus*	Hald.	x						
Lyogyrus	*pupoidea?*	Gld.	x						
Valvata	*tricarinata*	Say.						xx(4)	xx(3)
Campeloma	*milesii*	Lea.		x					
"						?(5)			
"	*decisa*	Say.	x						
Amnicola	*sp.*				x				
"	*porata*	Lea.	x						
"	*limosa*	Say.					x	x	
Bythinella	*obtusa*	Lea.							
"	*nickliniana*	Lea.	x		x				
Goniobasis	*livescens*	Mke	x	x	x	x	x		
"	*semicarinata*	Say.	x						
"	*depygis*	Say.	x						
"	*milesii*	Lea.	x						
Unio	*alatus*	Say.	x						
"	*asperrimus*	Lea.	x						
"	*cornutus*	Bar.	x						
"	*ellipsis*	Lea.	x						
"	*coccineus*	Hild			x				
"	*gibbosus*	Bar.	x				?		
"	*gracilis*	Bar.	x						
"	*ligamentinus*	Lam	x						
"	*luteolus*	Lam	x	x	x				
"	*nasutus*	Say.	x						
"	*novi-eboraci*	Lea.	x						
"	*phaseolus*	Hild	x						
"	*rectus*	Lam	x						
"	*rubiginosus*	Lea.	x						
"	*schoolcraftii*	Lea.	x						
"	*ventricosus*	Bar.	x		x				
Margaritina	*deltoidea*	Lea.	x						
Anodonta	*edentula*	Say.			x				
"	*fragilis*	Lam			x				
"	*benedictii*	Lea.	x						
"	*footiana*	Lea.	x		x				
"	*imbecilis*	Say.	x						

Genus.	Species.	Author.	Walkers list.	Loc. 6	5	4	3	2	1
Sphaerium	*striatinum*	Lam	x	x			x		
"	*simile*	Say			x				x
"	*securis*	Prime						x	x
"	*rhomboideum*	Say	x						
"	*occidentale*	Pme	x		x				
"	*partumeium*	Say	x						
"	*truncatum*	Lind	x						
Pisidium	*virginicum*	Lam	x						
"	*abditum*	Hald	x					x	x
"	*compressum*	Pme	x					x	x
"	*variable*	Pme	x					x	x
"	*contortum*	Pme				x	?x	x	x
"	"	Var ?						x (6)	x (6)
"	*rotundatum*	Pme						x	x
"	*scutellatum*	Sterki ?							x
"									

(1) Peculiar, two specimens, lacking the spire, whorls strongly shouldered, beneath which is a well marked constriction, which modifies the form of the aperture, lip sinuous, drawn back and somewhat expanded posteriorly, body whorl almost cylindrical.

(2) Spiral lines much more developed than is usual in living specimens. Many of the adult specimens are considerably corrugated transversely toward the aperture and after the period of the first growth. According to R. E. C. Stearns (Proc. Phila. Acad. Nat. Science, 1881, p. 104), such a tendency is evidence of considerable changes in temperature or environment.

(3) Exhibiting all stages from the unicarinate to the tricarinate form,—none ecarinate.

(4) Mostly bicarinate.

(5) See above, p. 249.

(6) See above, p. 249.

§ 3. Fossils of the Marshall and Coldwater by A. C. Lane and W. F. Cooper.

A list is given in the Proceedings of the American Philosophical Society (1870), Vol. XII, p. 389 including all the fossils which Winchell has described from this group. We can divide the 260 feet of the Lower Marshall (the Upper Marshall or Napoleon is so far as yet known unfossiliferous in the county) in two to three divisions, two of which we can also trace in the previous writers. The shales and intercalated sandstones below we can also divide into three zones. Having regard indeed only to our own collections we might subdivide some of these divisions, but as the subdivision grows finer the danger of placing forms in the wrong division increases with no compensating advantage, so that the division given below will suffice. At the same time in discussing our collections, the exact place in the column will be noted as far as possible.

The divisions we make are then:

(1) Lowest, the Rock Falls, Cuyahoga series, 176-553, especially 460 feet below the bottom of the Lower Marshall, =541 feet above the top of the Berea grit, with *Chonetes scitulus*, Plate X, Figs. 1 and 2.

(2) The Lighthouse Point series 100-176, especially 160-176 feet below the bottom of the Marshall as defined, very fossiliferous, with

Syringothyris pharovicina (Plate X, Figs. 5-7) and numerous spirifers, and a fair sized *Proetus missouriensis* and abundant Schizodus forms (Plate XI, Figs. 7, 9, 14, 15), generally larger than corresponding forms in higher horizons, which are, however, faunally closely allied.

(3) The Huron City series. 0—100 feet below the Lower Marshall, especially 84 feet below the bottom of the Marshall, Rhynchonelloids and Productus more abundant and smaller than in the Lower Marshall.

(4) The Point aux Barques series 85-260 feet below top of Lower Marshall, including the gritstones themselves (235-260), with fish remains and *G. Oweni,* zone of *Romingerina julia* above, at 220 feet, and all the strata up to the top of the Port Austin sandstone.

(5) The Solen series (65-85 feet below top), characterized by the abundance of Solen like forms and *G. marshallensis* including the richly fossiliferous zone of Hardwood Point, with *Prothyris meeki* (Plate XI, Fig. 10).

The upper beds, as exposed on the Port Austin and Port Crescent road,—thin-bedded flags, especially rich in small aviculoid forms, Leiopteria and Sanguinolites, Figs. 2, 11, 12, 13, Plate XI, this last zone not having been before observed in the county—are not an essentially new series.

(1). **The Rock Falls series** (Cuyahoga).

Like the corresponding Cuyahoga shales of Ohio, the blue shales are very poor in fossils, except in thin sandy seams and nodules of carbonate of iron, but Dr. Gordon discovered *Chonetes scitulus* a small delicate species, (? Chonetes of Rominger, Sp. 19147), and *Conularia gracilis.** Fucoidal remains, as suggested by Rominger (Caudagalli) in our specimen more likely worm-produced marks (Sp. 19148-19150), together with the Chonetes and Goniatites noticed by Rominger (III, 76) are not unlike the fauna of the Bedford and Cuyahoga (cf. Ohio VII, p. 32, 507) shale. Mr. G. H. Girty collected in the summer of 1897 with me also *Productus lævicosta,* and two other species, one probably *Productus blairi, Spirifer centronota,* Syringothyris, lamellibranchs, and heads as well as stems of crinoids. Cooper identified *P. Shumardianus,* and *P. newberryi* var. *annosus,* and *Streblopteria media, Phaethonides spinosus.* The other localities from from Port Hope down have not added to the list of species, but these suffice to identify it with the Cuyahoga of Central Ohio. The fauna is somewhat Devonian in aspect.

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*Ohio VII, Pl. XIX. Sp. 19146.

(2). Lighthouse zone.

Most of the fossils of this section come from the conglomerate and from one belt of sandstone about 3 inches thick.* The fauna is exceedingly rich. Not less than forty species and all the principal groups are represented. A characteristic feature of this fauna to be noted, is the comparatively large size of the forms. This is to be noted, not only as a whole, but in comparing any particular form with its nearest ally in the formations above. The minute ***Romingerina julia*** of series (4) is represented by larger terebratuloid forms, perhaps the form described by Winchell as *Merista Houghtoni*, compare Plate X, Fig. 13 (for in default of knowledge of the internal structure, these forms may be wrongly attributed to different genera). The Proeti have glabellas 15 mm. or so long (Plate XI, Fig. 14), while the next trilobite that we notice (Sp. 19094) is almost microscopic. The lamellibranchs and brachiopods are also large, often attaining a length of 20 to 40 mm, and the rhynchonellas attain about twice the size of those higher up in the series (Plate X, Fig. 8, 9, 10).

SPIRIFER SUBATTENUATUS, Hall? (Proc. Acad. Nat. Sci., Phila., 1862, p. 405).

Winchell says merely that the form agrees with Hall's descriptions and in the Proceedings of the American Philosophical Society he speaks of it as a doubtful identification. At least four, probably more of the Spirifer family are found by us, some with, some without striations in the sinus, sometimes fasciculated. Compare Sp. 19049, 19045. This is a small Spirifer, but our forms appear rather too elongate, more of the mucronatus type.

SPIRIFER MEDIALIS, Hall? The specimens, here and there, through the whole series 19044 to 19089 show another type of flatter, and not very large spirifer. Winchell's identification is almost certainly erroneous.

SPIRIFER HURONENSIS, Win. is described as follows, P. A. N. S., Phil., 1862, p. 407. This we have figured, Plate X, Fig. 3. Compare *S. **deltoideus***.

"*Spirifera Huronensis*, n. Sp. Shell of medium size, transversely semi-elliptic, with acuminate hinge-extremities; entire hinge-length nearly three times the length of the shell; anterior and antero-lateral borders regularly curved. Ventral valve ventricose, especially towards the beak, which is erect over a high triangular area, triangularly foraminated at the apex; sinus beginning near the beak, not well defined, round at its margins and bottom; entire surface covered with about forty rounded ribs, of which the lateral half on each side terminate upon the cardinal border, while about four of the same size as their neighbors, occupy the sinus. Dental plates standing at an angle of 58°. Dorsal valve equally tumid with the ventral; beak incurved over a narrow area; mesial fold indistinct, with three or four ribs; occlusor and pedicle scars lanceolate, deep. Surface of shell with one or two squamous incremental lines.

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*See pp. 25, 87.

"Length of shell, in inches, .49 (100); length of hinge line 1.3 (265); convexity of ventral valve .25 (50).

"Locality. Lighthouse Pt. aux Barques, in a hard, gray, pyritous, coarse, often conglomeritic bed of sandstone two feet thick, intercalated in the argillaceous slates of the Huron group."

Specimen 18263 and 19048, seem to show this type of spirifer well. It will be noted that there is nothing in the description of this and the next species to prevent its being a Syringothyris, which it may be.

SYRINGOTHYRIS PHAROVICINA, Win. described, Proc. Acad. Nat. Sci. Phil., 1862, p. 406, as follows, under the name *Spirifer pharovicina*:

"Shell large and ventricose. Ventral valve with a gentle sinuation which extends to the beak; dental plates moderately long, forming an angle of 80°; area very elevated, with a narrow triangular fissure reaching to the apex, which scarcely overhangs the area; surface faintly marked each side of the sinus by rather remote radiating ribs, which, near the margin, are somewhat distinct. Some impressions of areas supposed to belong to this species, are 2.1" [inches] "long, and .95 high, with a fissure .44 wide at base; deltoidal impression grooved in the direction of the fissure; surface of area flat, slightly incurved at apex and marked by very distinct transverse striae. Dorsal valve with a low rounded fold, marked (in the cast) by a single small median groove, beak prominent, incurved over a small area."

Locality. Lighthouse, Pt. aux Barques, with *Rhynchonella Huronensis, Spirifera Huronensis,* etc.

This well known species is known only by imperfect casts.

I feel quite confident that this is a Syringothyris (and so do Cooper and Girty). The large suite of specimens, 19044, 19265, and 19266, Plate X, Figs. 5, 6 and 7, show a Syringothyris, which is one of the commonest and most characteristic fossils of the series, as Rominger also noticed. It is hardly possible that Winchell could have not found any representative of it, and it is doubtless his species which we figure and his description of *Spirifer pharovicina* agrees precisely with our specimens of Syringothyris, except obviously that the characteristic structure of Syringothyris did not show and is not described by him, but there is nothing inconsistent in his descriptions. In fact he did not found the genus until next year. It is very common and some variation in the height of the area, suggests that a form like *Syringothyris herricki* may be present also.

SPIRIFERA? (cf. *ATHYRIS*) *INSOLITA*. Described as follows, Proc. Acad. Nat. Sci., Phil., 1862, p. 406.

"*Spirifera* (?) *insolita*, n. sp. Shell large, smooth. Ventral valve with a broad, concave sinus reaching to the beak, and forming at its lateral margins angles with the shell surface; area short and imperfectly bounded, though the beak is rather high; dental plates very long, reaching the middle of the shell or beyond, and forming with each other an angle of 25°, which is the same as the rostral angle of the mesial sinus.

"Locality. Lighthouse. Pt. aux Barques.

"The species has the short hinge line of Brachythyris, and the smooth surface of Martinia—characters which, with the very long and approximate dental plates render it unique among Spiriferæ."

Schuchert classes this as a Martinia, and it is surely not a Spirifer.

EUMETRIA (?) POLYPLEURA. Plate X, Figs. 13 and 14. Described as follows, Proc. Acad. Nat. Sci., Phila., 1862, p. 406.

"*Retzia Polypleura*, n. sp. Shell of medium size or rather large, cuneate-oval, tumid. Ventral valve with a prolonged, isolated, nearly erect, perforate beak, which projects one-fourth the valve length beyond the dorsal valve, a swollen umbo, and depressed central and anterior region. Dorsal valve rotund, with a subcuneate rostral margin; beak obtuse, closely appressed against the ventral valve; umbo ventricose; entire valve with a regular cardium-like convexity; median ridge extending one-third the length of the valve, with a lanceolate occlusor impression on each side of it. Surface marked by about forty small, rounded, radiating ribs. Spires not seen.

"Length, breadth and thickness of a rather small specimen: .70" inches "(100), .58 (83) and .34 (50). Length of dorsal valve .52 (74). Length and breadth of another dorsal valve .69 and .66."

"Locality. Lighthouse, Pt. aux Barques with *Rhynchonella Huronensis*, etc. This species resembles *R. serpentina*, de Kon. (Anim. Foss., 291, pl. xix, 8). but the ventral valve is most ventricose in the umbonal instead of the middle region, and has a nearly erect instead of a straight beak. It differs from *R. vera*, Hall (Iowa Rep. 704, pl. xxvii), in the absence of wings, and in its more erect beak."

These forms seem to be represented by specimens 19073, 19267, 19268. The two specimens which we have figured are from the conglomerate where they are most abundant.

MERISTA HOUGHTONI. Described as follows, Proc. Acad. Nat. Sci., Phila., 1862, p. 407.

"Shell of medium size, subrotund and subtumid. Ventral valve a little produced at the straight, obtuse foraminated beak, somewhat truncate in its contour, along the cardinal slopes, and very slightly elongate in front across the width of the sinus; regularly convex in all directions from the middle, except along the shallow sinus, which takes its origin near the middle of the valve. Impressions of the divaricator muscles longitudinally striate. Dorsal valve circular; beak scarcely projecting beyond the hinge; occlusor impressions small, spatulate, separated by a rostral septum reaching one-fourth the length of the valve; mesial fold represented by an undulation at the anterior margin. Surface of cast smooth.

"Length, breadth and thickness .70 (100), .68 (97) and .36 (51).

"Locality. Lighthouse, Pt. aux Barques, with *Rhynchonella Huronensis*, etc."

It will be noticed that the description does not rule out some allied genera. A number of specimens contain terebratuloid forms, as Sp. 19073.

PLEUROTOMARIA HURONENSIS described, Proc. Acad. Nat. Sci., Phila., 1862, p. 425, as follows:

"*Pleurotomaria Huronensis*, n. sp. Shell rather large, depressed-turbinate, consisting of about four very rapidly enlarging whorls. Body whorl flattened from above, moderately convex above; the base a twisted plane bounded on one side by the slope into a large open umbilicus, on the other, by the sharp whorl marked by eleven raised plications and intervening broad sulci, of which, counting from the umbilicus, the sixth rests upon the carina, and the eleventh is close to the suture. These are crossed by striæ of growth rising from the umbilicus, stretching far forward upon the base, curving backwards and just before reaching the carina, and apparently curving forward again after passing it.

"Height of shell 1.00 'in inches' (100); diameter of base 2.00 (200); transverse diameter of aperture .92 (92).

"Locality. Lighthouse, Pt. aux Barques, in intercalated sandstones of the Huron group.

"This species recalls *Euomphalus carinatus*, Sow., (Murch. Sil. Syst. 616, Pl. VI, Fig. 10)."

Our specimens, 19051, 19070, 19075, agree exceedingly well.

CAMAROTŒCHIA HURONENSIS, described as follows: Proc. Acad. Nat. Sci., Phila., 1862, p. 409:

"*Rhynchonella Huronensis*, n. sp. Shell of medium size, tumid, transversely oval, or nearly circular, with rounded lateral, and cuneate rostral margins. Ventral valve with a straight beak, flattened in the central region, and rather abruptly inflected around the margin toward the plane of the valve; mesial sinus beginning with the last third of the shell-length, and consisting of a sudden depression in the antero-marginal slope. Dental lamellae well developed, very slightly divergent. Dorsal valve with an inconspicuous beak and a mesial fold abruptly elevated and confined to the anterior third of the valve; median septum reaching two-fifths the length of the valve. Occlusor muscular impressions semi-elliptic, lying close to the median septum. Shell structure fibrous. Surface marked with 23 small rounded ribs, of which five occupy the mesial sinus.

"Length of the ventral valve .48 "inches" (100); breadth .58 (121); convexity .10 (21).

"Locality. Lighthouse, Pt. aux Barques, in a hard pyritous sandstone, intercalated in the argillaceous slates of the Huron group.

"Var. *precipua* differs from the typical forms in being more flattened on the ventral side, with mesial sinus consisting of an abrupt deflection of nearly the whole anterior margin of the valve, forming a right angle with the plane of the valve; surface with 18 rounded radiating ribs, of which 6 fall in the sinus; dental plates diverging at an angle of 40°."

Both these varieties can be recognized in Specimens 19051, 19271, 19272 and numerous other specimens of the suite, and are like *R. sappho*, etc., Sp. 19058, Fig. 1 and Fig. 18 of Herrick's Plate XXI.* The forms figured on Plate X, Figs. 8, 9 and 10, are the variety *precipua*.

ORTHIS VANUXEMI HALL. The shells referred here by Winchell are not quite like the type and are thus described (Proc. Acad. Nat. Sci., Phila., 1862, p. 409). The kindred forms in the Lighthouse section are a little larger. (Sp. 19072.)

"*Orthis Vanuxemi*, Hall (10th Ann. Rep. N. Y. Reg., p. 135). Shell nearly circular, sub-tumid; hinge-line very short. Dorsal valve a segment of a sphere; beak not surpassing the hinge, slightly incurved; a thick median plate or ridge reaching nearly to the centre of the valve, bisecting the right angle formed by the well developed socket ridges. Ventral valve flat, or slightly concave anteriorly, with a projecting beak; median ridge feeble, extending scarcely to the mid-valve; a barely perceptible trace of the semi-circular divaricator impressions sweeping from the beak to the anterior extremity of the median ridge, in the middle of which space are the two small semi-elliptic occlusor scars; dental plates short and thick; teeth well developed, lying in the hinge-line. One of the casts differs in having one of the occlusor scars half heart-shaped and the dental plates more slender. Surface not fully known; marked by numerous radiating striæ which increase by implantation and bifurcation, and produce a crenulated anterior margin. Shell structure finely punctuate.

"Length .81 (100); breadth .81 (100); thickness .25 (31).

"Locality. Lighthouse, Pt. aux Barques, with *Rhynchonella*

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*Geology of Ohio, Vol. VII.

Huronensis, etc. This shell is a little more convex in the dorsal and flatter in the ventral than the figures given by Prof. Hall, but none of its characters differ materially from his description. Compared with *O. Michelini*, Lev., as described by de Koninck, it is a little more convex dorsally, and presents circular instead of digitate (from the vascular system?) divaricator impressions upon the ventral valve. *O. Vanuxemi* is described from the shales and shaly sandstones of the Hamilton group of New York and Iowa, the lithographic limestones of Missouri, and from the soft sandstones in Eastern Ohio, regarded as Chemung by Prof. Hall."

DERBYA CRASSA is the present name for *Orthis crenistria.* The forms which Winchell thus referred are described as follows (Proc. Acad. Nat. Sci., Phila., 1862, p. 410):

"*Orthis Crenistria*, Phillips. (Pal. Foss. Corn., etc., p. 66, Pl. 27, Fig. 113),—Hinge line equal to greatest width of shell; ventral valve semi-elliptic with shallow constrictions beneath the cardinal extremities; flat, with an umbonal elevation beginning about the middle and rising to a beak which overlooks a large triangular area inclined at an angle of 45° with the shell plane; dental plates strong, each equal to one-fourth the hinge length, forming with each other an angle of about 60°. Occlusor scars reaching nearly the middle of the shell, closely contiguous, leaving together a ligulate anteriorly acute depression upon the cast. Surface covered by fine radiating striae, interrupted by distinct or obscure concentric wrinkles. In one specimen supposed to belong here, the surface is cut by a set of sharply-cut, twice dichotomizing striæ—the second set reaching half way, and the third one-third the distance to the beak. Dorsal valve hemispherically convex with sharp striæ and concentric wrinkles, like the ventral.

"Length of shell, 1.27 (100); length of hinge line 1.37 (107; length of the dental plates .32 (25).

"Locality. Lighthouse, Pt. aux Barques.

"I can make no distinction between this species and that described by Phillips, from South Devon. The beak, however, seems to be perfectly symmetrical, and in this it differs from *Streptorhynchus robusta* Hall, Sp., from the coal measures of Iowa, as well as from the Punjab examples of Davidson (Quar. Jour. Geol. Soc. Lond., XVIII, p. 30), who identifies the Devon, Iowa and Punjab forms. The Michigan forms differ from all the others in the rugose exterior, giving it sometimes the aspect of *Strophomena rugosa*; but as they at the same time differ among themselves, I am not disposed to hesitate in the identification."

What Winchell seems to have in view are forms like Sp. 19045, 19060, very likely a *Streptorhynchus*, or *Derbya*.

ORTHIS IOWENSIS? described Proc. Acad. Nat. Sci., Phila., 1862, p. 410, as follows:

"*Orthis Iowensis?* Hall. (Io. Rep., p. 488, Pl. 2, Fig. 4.) Some casts in my possession resemble those of the above species. Ventral

valve nearly circular, regularly convex, with deep pit in the beak between the dental plates, which in the cast produces a conical projection. Middle region of cast with three faint rounded ridges radiating from the beak to the anterior margin.

"Locality. Lighthouse, Pt. aux Barques."

Perhaps this is represented in specimens 19073.

To this list of Winchell's Rominger adds without giving specific names or descriptions a number of genera which are undoubtedly present, viz.:

Productus. Compare our specimen 19062, probably two species, not very large.

Syringothyris. Compare what we have said above under *Syringothyris pharovicina*. The syringothyrids are among the abundant and characteristic fossils.

Streptorhynchus. The species is probably the same as that referred to *Orthis crenistria* by Winchell, the two names being more or less synonymous. Cf. Sp. No. 19067.

Rhynchospira, is very likely the same as the *Eumetria polypleura*, Cf. Sp. 19073, and Plate X, Figs. 13, 14.

Spiriferina. Most of the specimens being casts we are not able to identify this form with any certainty.

Terebratula. This genus we have not been able to identify. It may have been the Merista.

Cypricardella (*barquensis*). The hinges not being generally in good state of preservation, the generic references of all the lamellibranchs are more or less uncertain. Compare Sp. 19057. Compare also Cypricardia and Sphenotus below. Winchell also mentions a *Cypricardella barquensis* (Proc. Am. Phil. Soc., 1870, p. 393) as occurring in Northern Michigan, i. e., Huron county, but if from the Lighthouse section he would not have included it in the Marshall. Rominger may have seen the species which we figure as *Microdon reservatus* (Plate XI, Fig. 3).

Schizodus apparently extremely common and abundant. The forms usually resemble extremely those figured by Herrick on plate XVII, of Vol. VII of the Ohio reports. Cf. Sps. 19045 and passim to 19073, 19082, 19260. We figure on Plate XI, Figs. 7 and 8, *Schizodus triangularis*. Many of these shells and many of the Spirifers seem to have been slightly crushed in making the cast, being flattened and cracked on the more tumid part.

Aviculopecten. Pectinoid forms are quite common, see Specimens

Nos. 19050 and 19062, but I judge belong mainly under Crenipecten, being similar to *Crenipecten caroli*. Compare the new form figured by Cooper as *Aviculopecten areolatus* (Plate XI, Fig. 1).

Goniatites.

Proetus, the glabellas and pygidia of a species of Proetus are extremely common, more rarely, a cheek spine or bit of the thorax may be found (Specimens 19045, 19280 and 19281, and passim through the suite). It is identified by Cooper as *P. missouriensis* Shumard (Plate XI, Figs. 14, 15) described below. No whole specimen has been found here.

Cyathocrinus. Shorewashed fragments of crinoid stems of more than two species are not uncommon. Mr. Cooper has found one head. (Specimens, 19068, '69, '70, '73.)

Bryozoa. Fenestelloid forms are not uncommon, but so far have been found very poorly preserved. (Specimen 19053.)

Besides the above forms we have obtained in our recent collections, forms like the following species.*

Nautilus strigatus, Sp. 19047 (only a small fragment); compare also Sp. 19053.

Nuculites, Sp. 19056 shows a row of teeth on the hinge, the general shape is much like *Cucullella cultrata.*

Spirifer centronatus Win., Cf. Sp. 19061.

Solen priscus (not solen, solenopsis?). Sp. 19064, 19045, round with flaring ends.

In addition to the re-identification or more specific identifications which have already been mentioned Mr. W. F. Cooper has determined the following species (one of which proved, after figuring, to be new).

SPIRIFER DELTOIDEUS Herrick.

1888. *Spirifer deltoideus.* Herrick, Bull. Denison University, Ohio, Vol. IV, p. 27, Pl. 2, Fig. 7.

1895. *Spirifer deltoideus.* Herrick, Geol. Survey, Ohio, Vol. VII, Pl. 15, Fig. 7.

The description of this species as originally given is as follows:

"Shell of medium size, quite gibbous, triangular in outline, hinge equalling the extreme width; anterior margin angulated in the middle, forming with the hinge roughly an isosceles triangle of 45°; hinge apparently not, or but slightly mucronate. Dorsal valve prominently convex along the longitudinal axis, rather strongly arched; beak moderately prominent, fold triangular, rather high, sides of shell sloping rapidly from it toward the sides. Surface covered by nearly sixty small rounded, persistent striæ, which rarely bifurcate near the front. From eight to ten striæ fall upon the fold which in spite of its prominence (and because of the similar convexity of the valve) is poorly defined. Ventral valve very convex, provided with a deep, triangular, but narrow sinus and sculptured on the dorsal valve. Width of dorsal valve, 37 mm., height 29 mm.

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*Study has not been careful enough, nor opportunity of identification, and in many cases state of preservation good enough, to warrant any decided identifications as yet.

"All the specimens are casts of separate valves in the sandy parts of conglomerate I. There is reason to accept the suggestion made in the last volume, that this species forms a link between the *S. marionensis* and *S. stratiformis*."

Formation and Locality. In the conglomerate bed at Point aux Barques light, Huron county, Michigan. This species was originally described from the same horizon at the Dugway quarry three miles west of Newark, Ohio, where it is found in conglomerate I. Michigan Geological Survey Collection, No. 19264. (Plate X, Fig. 4 of this report.

AVICULOPECTEN AREOLATUS, n. sp. Cooper [Crenipecten?] Plate XI, Fig. 1.

Shell sub-ovate, oblique to the hinge line; length slightly greater than the height; anterior and basal margins regularly rounded. Left valve slightly convex, reaching its greatest convexity at about one-third the length of the valve from the beak. Hinge line straight, having a length equalling three-fifths of the greatest length of the shell. Beak well defined, projecting slightly beyond the hinge line. Ears triangular, equal, the anterior one meeting the body of the shell at a more obtuse angle. Test ornamented with about 65 sharp rays of unequal size which are crossed with finer concentric striæ. In the anterior portion of the shell the rays are arranged in irregular fasciculi which are crowded out towards the hinge line. On the specimen before us the first 15 rays below the anterior ear have a tripartite division and converge in three bundles towards the hinge line. This feature is sufficient to separate it from any other species of which I know.

Formation and Locality. From the sandstone layer at Point aux Barques light house in the upper Coldwater, i. e., middle Waverly group. Michigan Geological Survey, Collection No. 19278.

EDMONDIA CF. BINUMBONATA A. Winchell. Figured here, Plate XI, Fig. 5.

"Shell medium size, quadrate; height equal to two-thirds the length; basal margin slightly arcuate in the middle, regularly curving into the anterior and posterior extremities. Anterior end straight, regularly rounded underneath the umbonal ridge, forming with the slightly arcuate posterior portion an expanding margin which increases dorsally. Cardinal line nearly straight. Right valve regularly convex, the greatest convexity being in front of the center of the shell. Principal umbonal slope running to the posterior extremity of the ventral border, a shorter one almost equally elevated, extending to the anterior extremity, which is more abruptly elevated than the posterior end. Beaks depressed and incurved. Surface marked by fine, concentric striæ, which are unequally fasciculate, sometimes making conspicuous varices of growth."

This species is not identical with the form described by Winchell as *E. binumbonata*, which is a Schizodus. The hinge line is not short posterior to the beaks as in his description. From *Schizodus subovata* Hall, it may be distinguished by its straight anterior end and depressed beak which does not extend over the hinge as in that species.

Formation and Locality. The specimen here figured is from the light house at Point aux Barques, Huron county, where it occurs in the Coldwater or middle Waverly formation. Michigan Geological Survey Collection, 19277.

SPHENOTUS ÆOLUS Hall. Figured here, Plate XI, Fig. 6.

1870. *Sanguinolites æolus.* Hall. Pal. N. Y., Vol. V, Part I, Prel. Not. Lamell, 2, p. 46.

1875. *Sanguinolites æolus.* Meek. Pal. Ohio, Vol. II, p. 307, Pl. 16, Figs. 1a-c.

1885. *Sphenotus æolus.* Hall. Pal. N. Y., Vol. V, pt. I, p. 404, Pl. 66, Figs. 31-35.

188. *Sanguinolites æolus.* Herrick, Bull. Denison University, Ohio, Vol. III, p. 70, Pl. 8, Figs. 1, 11.

This species which has been admirably described by Meek in Volume II of the Palæontology of Ohio is stated by him as coming from the Cuyahoga shale at Medina county, Ohio, from the same horizon as at Newark, Ohio. As Orton and Herrick limit the term these beds do not form a part of the Cuyahoga series. At Newark, Ohio, the sandstone beds which almost uniformly form the quarry rock in central Ohio, are a part of the middle Waverly or lower Logan and are at least 40 feet above the typical Cuyahoga, which in Licking county outcrops farther west. In Huron county this form is of value as coming from beds of the same horizon (middle Waverly), and lithological character as outcrops in a north and south line from Portsmouth, Ohio, to a point north of Wooster.

Shell elongate, ovate, posterior end regularly rounded, anteriorly it slopes abruptly from the beak with a distinctly concave outline to the most prominent part of the front margin which is above the middle, narrowly rounded below; basal margin straight or slightly elliptical, sub-parallel to the base; cardinal line nearly straight or slightly convex; beak, small, well defined, depressed, projecting forward and placed about one-seventh the distance from the anterior end of the shell.

Surface marked with rather distinct concentric lines with furrows and ridges which have a tendency to become well defined anteriorly.

Formation and Locality. From the middle Waverly or lower Marshall at Point aux Barques light house. Mich. Geol. Survey Coll. No. 19260.

SCHIZODUS TRIANGULARIS, Herrick. Figured, Plate XI, Figs. 7 and 8.

1888. *Macrodon ? triangularis*. Herrick; Bull. Denison University, Ohio, Vol. III, p. 74, Pl. VIII, Fig. 8.

1888. *Schizodus triangularis*. Herrick; Bull. Denison University, Ohio, Vol. IV, p. 116, Pl. VI, Figs. 10, 13.

1895. *Schizodus triangularis*.. Herrick; Geol. Survey, Ohio, Vol. VII, Pl. XVII, Figs. 10, 13.

Shell medium, subtriangular in outline, convex; hinge line very short; anterior end slightly convex, contracted beneath the beak and rounded below, ventral line gently convex anteriorly, incurving anterior to the umbonal ridge; posterior margin nearly straight, very oblique to the hinge; post-umbonal slope abrupt, slightly concave, anteriorly the umbonal ridge is gently rounded and depressed anterior to the ridge, producing a deflection in the ventral margin; umbones rather broad, depressed, projecting beyond the hinge line.

This species is more nearly related to *S. aequalis* Hall, than any other form, but the beak is not sub-central as in that species, and the posterior margin is less produced.

Formation and Locality. Abundant in the middle Waverly or lower Logan sandstone above the conglomerate at Point aux Barques lighthouse, Huron county, Michigan. This species is also found in the same horizon at Granville, Licking county, Ohio. Michigan Geological Survey Collection 19256, 19257.

SCHIZODUS BINUMBONATA cf. *ÆQUIMARGINALIS* Winchell. Proc. Acad. Nat. Sci. Phila., 1862, p. 413. Figured here; Plate XI, Fig. 9.

The original description reads as follows:

"Shell of moderate size, rotund quadrate, very tumid. Hinge line short, posterior to the beaks; posterior margin forming with it a very obtuse angle; anterior slope straight, forming a rounded right angle with the slightly curved ventral border which is nearly parallel with the hinge line, and joins the posterior slope by a regular curve. Beaks depressed and incurved; greatest thickness through the middle of the shell; principal umbonal slope running to the posterior extremity of the ventral border; a subsidiary one running to the anterior extremity; between these the surface is subcylindrical; anterior to them it descends abruptly to the anterior margin, while behind them it sinks at first rather abruptly, and near the posterior border presents a little flattening. Surface (of cast) marked by eight or ten concentric furrows. Anterior lunule excavated.

"Distance measured along the principal umbonal slope (in inches) .85 (100); length from anterior to posterior extremity .85 (100); anterior slope .59 (69); convexity of right valve .24 (28); angle between anterior cardinal slope and principal umbonal line 70°."

Formation and Locality. The type species is described as coming from Marshall. The form here figured is from the Upper Coldwater (Cuyahoga) as that term is now understood; from Point aux Barques lighthouse, Huron county, Michigan. This is equivalent to the middle Waverly or lower Logan of Ohio. Michigan Geological Survey Collection, 19262.

PROTHYRIS MEEKI, Winchell. Plate XI, Fig. 10.

1875. *Prothyris meeki*, Winchell (Ms.) Pal. Ohio. Vol. II, p. 305, Pl. XV, Fig. 2.

1888. *Prothyris meeki*, Herrick, Bull, Denison U., Ohio, Vol. III, p. 66, Pl. VIII, Fig. 7.

1888. *Prothyris meeki*, Herrick, Bull, Denison U., Ohio, Vol. IV, Pl. IV, Fig. 2.

1895. *Prothyris meeki*, Herrick, Ohio Geol. Survey, Vol. VII, Pl. XVI, Fig. 2.

Shell varying from narrowly elongate to elongate; rhombic in shape, greatest width about one-third the length; dorsal and ventral margins sub-parallel, the lower margin being either straight or slightly arcuate, while the cardinal line in normally preserved specimens is convex, the greatest convexity being usually about one-third distant from the posterior end; umbonal ridge well defined trending towards the ventral portion; ventral portion of the umbonal ridge depressed from the central portion of the basal margin to the beaks; beak depressed, situated about one-sixth the distance from the anterior end.

Surface marked with concentric lines of growth.

Formation and Locality. This species is found in central Ohio in strata either above or below the conglomerate II in the Waverly. The specimen here figured is incompletely preserved. It is from the sandstone beds over the conglomerate at Point aux Barques lighthouse, Mich. Geol. Sur. Collection No. 19261.

PROETUS MISSOURIENSIS, Shumard. Plate XI, Figs. 14, 15.

1855. *Proetus missouriensis*, 1st and 2d Geological Rep. Missouri, p. 196.

1862. *Proetus auriculatus*, Hall, 15th Rep. N. Y. State Cab. Nat. Hist., p. 107, and Pal. N. Y. Vol. VII, p. 133, Pl. III, Fig. 32.

1895. *Proetus auriculatus*, Herrick, Geol. Surv. Ohio, Vol. VII, Pl. XIV, Figs. 14, 15.

For description of this species the student is referred to the preceding publications. The glabella and pygidium (head and tail shields) are figured here on account of the value in connection with the associated fauna. In Licking county, Ohio, it only occurs in the freestones of the middle Waverly between conglomerate I and II. Its position at Point aux Barques lighthouse is just over the conglomerate where it is found very abundantly along with *Schizodus triangularis*. The specimens here illustrated came from that horizon and place. Mich. Geol. Sur. Collection, 19280, 19281.

ORTHOCERAS BARQUIANUM, Win. described as follows, Am. J. Sci., (Second series) XXXIII, p. 356.

"Septate portion of shell more than 4¼ inches long; greater apical angle (i. e. the one formed by the sides which are not compressed), about 10°; tranverse section an ellipse whose minor axis is to the greater as .35: .50 = 1.43; septa somewhat oblique, making an angle of 8° to 10° with a transverse plane; most elevated near one extremity of the longer diameter; amount of concavity and position of siphon unknown; distance between the septa about one-fifth the greater axis at the same place. No surface markings evident from an examination of casts.

"Locality. Near the lighthouse at Point aux Barques in a hard bluish sandstone embraced in the shales of the Huron group. (See Huron group, (c) of the preceding table).

"This species may possibly prove identical with the preceding, but its apical angle is somewhat less, its septa more oblique, its section more eccentric, and its geological position considerably lower."

In the shaly beds of the Lighthouse Point section we find much the same fauna as that which is from the sandstone layers, mainly D. of p. The Producti and *Orthis vanuxemi* or Chonetes are more prominent. We have also Camarotœchia and apparently ostracoda. Sp. 19076, 19077. There are also flattened spirifers (Sp. 19075-19078).

A very calcareous facies shows Syringothyris and crinoids still abundant. The very purest shale is, however, nearly destitute of fossils. Among the bryozoa there are two types well recognized though poorly preserved, the one like *Fenestella*, the other rounded branching forms, Sp. 19082, more of the *Stictopora* type preserved only in casts.

Though not a fossil, the interesting bit of black shale, almost coal, rounded and polished like jet, which occurs as a fragment in the conglomerate should be noted in this connection.

Taking the lamellibranchs first, the abundance of Schizodus, and Pecten forms, indicate the Carboniferous. Among the more obscure forms, the thin shelled casts of forms like Sanguinolites, Cypricardella, Sphenotus, Solon or Solenopsis, thin gaping mollusks with anterior beaks is also according to Zittel indicative of the Carboniferous.

Among the brachiopods the Terebratula, Retzia and Merista forms, are too uncertain in generic identification, and too little characteristic anyway to count for much, though the Athyris or Martinia is rather Carboniferous.

The numerous species of Spirifers, have both Devonian and Carboniferous forms, though the presence of so many forms with a striated sinus, leads one to think of the Carboniferous. The Spiriferina would point the same way; the Syringothyris is even more strongly indicative. The trilobite almost certainly *Proetus missouriensis* points to the early Carboniferous or Devonian. The Orthis points the same way, though the large flat forms like *O. michelini*, and the forms like Streptorhynchus and Derbya, are also early Carboniferous.

The Rhynchonellas mean little, but the Producti are significant of the Carboniferous. Being rather small we think first of the lower Mississippian.

The Orthoceras is pre-eminently early Palæozoic, though abundant yet in the Carboniferous.

Taken altogether we incline to override Winchell's judgment[*]

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[*] A. Phil. Soc., 1870, p. 386.

and assign this horizon as well as those above to the Carboniferous. On this connection we must not overlook the pebble of coaly shale. If this be from the Genesee, the Devonian black shale, it indicates that some part of the Devonian, had been turned to coal, elevated and eroded before the epoch of the Lighthouse conglomerate. This test is commonly used in Archæan geology for making the greater divisions.

We have noticed in Chapter II that Winchell in assigning these strata to the Devonian seems to have done so on the principle of giving your opponent the most possible. On a doubtful identification of four species, he yields this much to those who wished to claim the whole series as Devonian, saying "that the equivalencies of these rocks are not very precisely indicated from palæontological data."

When we compare with Herrick's lists, we see that we can find possible synonyms for almost every one of our forms in his lists of forms within 30 feet above and below Conglomerate I, at the base of his division II or Kinderhook. Yet the lists and forms do not appear to be precisely the same. The extreme wealth of fauna, and especially the occurrence of different species of the same genera, suggests an intermixture of two faunas in process of migration (and rapid evolution?) so that, for example Syringothyris may have existed a little earlier in Michigan than in Ohio, and Orthoceras like *O. rushensis* a little later. Plate X, Figs. 3 to 10, 13, 14 and Plate XI, Figs. 1, 5, 6, 7, 8, 9, 14, 15, give a view of some of the more characteristic forms.

(3). **Huron City zone.**

No fossils appear to have been collected from this belt by Winchell, and he probably* considered these sandy beds at Huron City as equivalent to the quarry beds at the base of his Marshall, whereas they are really some 84 feet below the quarry beds. Rominger notes a Rhynchonella as abundant, and Productus as also present. He mentions *Fucoides Cauda galli?* on surface of the same bed.

CAMAROTŒCHIA (RHYNCHONELLA) CAMERIFERA, Sp. 19036, 19273, 19274, Plate X, Figs. 11, 12; many specimens agree better with this species than any other described by Winchell, and are very abundant, somewhat smaller than the rhynchonellas of Lighthouse Point. Others show hardly any mesial sinus, and otherwise agree with Winchell's descriptions of other species.

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*Report 1860, p. 74.

The original description of the species is given by Dr. Winchell:

"Shell of moderate size, tumid; beak of ventral valve projecting and slightly upturned; cardinal slopes straight, at right angles; sides of the shell rounded; front margin similarly rounded or somewhat straight, not infrequently produced on one side of the mesial sinus. Dorsal valve nearly circular, a little more covered than the ventral, most convex anterior to the middle, and rather abruptly bent down in front. Ventral valve with a shallow sinus, which extends back about one-fourth the length of the valve, corresponding to the fold in the dorsal valve; most convex between the beak and the middle; dental plates parallel, well developed, teeth at right angles, elongate, growing stouter anteriorly, with handsomely crenulated margins; mesial partition of the dorsal valve, extending nearly one-half its length, thickening near the beak, to give place for the excavation of a small chamber near the septum. Shell with 20 or 21 (a variety ? with 16) sharp plications, of which three or four are comprised in the mesial sinus; these are crossed by a few squamose concentric wrinkles; shell structure fibrous.

"Length of an average specimen" [inches] ".38 (100); breadth .34 (90); thickness .19 (50)."

Formation and Locality. The type species is found most abundantly on the road leading west from Grindstone City and in the valley of Willow river about 3 miles south of Huron city, with *Romingerina julia.* The species here figured are from the bed of Willow River near Huron City.

"Locality. Point aux Barques, in a conglomeratic ferruginous sandstone overlying the gritstones of the Marshall group—myriads of casts sometimes forming, with *Centronella julia,* the whole mass of the rock.

"The small chamber in the mesial septum of the dorsal valve is an interesting and unique character. On a similar cameration of the septum of the ventral valve of some Cyrtiæ the genius Cyrtina has been founded; and Prof. King established his Camarophoria on the formation of an arch in the ventral valve by the approximation of the dental planes.

"This species has the external appearance of the young of *R. increbescens,* but amongst thousands, none attain proportions very different from those given above."

This associated with *Romingerina julia*, makes a well marked zone, 220 feet below the top of the Lower Marshall and forty feet above the grindstone beds.

Productus is still small.

Scolithus, flattened, nearly vertical tubes, worm borings or as likely tracks of some lamellibranch. Sp. 19036.

Schizodus triangularis, smaller than some at Lighthouse Point, but almost exactly like others, about 20 mm. long, Sp. 19037.

Myalina, cf. *whitfieldanus*. Sp. 19037. a small pointed form.

Sphenotus? Sp. 19037.

Crenipecten winchelli? There are a number of pecten fragments. Sp. 19039. and it is characteristic that the ribs are bifurcated. What seems to be a smaller species is more marked by squamous lines of growth. These are not Lyriopecten, but may be Crenipecten.

There is also the cast of the umbilicus of some gastropod like *Pleurotomaria?* Sp. 19041.

There is a small *Nucula* form about like *N. iowensis*. Sp. 19040. Specimens 19038 and 19042 are fossil forms that I cannot determine, even approximately.

MICRODON RESERVATUS Hall. Figured here. Plate XI, Fig. 3.

1870. *Microdon reservatus*, Hall, Pal. N. Y., Vol. V, Part I, Prel. Not. Lamell., 2, p. 33.

1885. *Microdon reservatus*, Hall, Pal. N. Y., Vol. II, Pt. I, p. 312; Pl. 74, Figs. 11-13.

1888. *Microdon reservatus?* Herrick, Bull. Denison Univ. Vol. III, p. 75, Fig. 14.

1895. *Microdon reservatus*. Herrick, Geol. Survey, Ohio, Vol. 7, Pl. 17, Fig. 9.

This species which is found abundantly in the freestones of the middle Waverly or lower Logan, Licking county, Ohio, and in the valley of Willow river, south of Huron City, Michigan, is rather above medium size, rhomboid ovate, slightly convex; beak (situated two-sevenths from the anterior end of the shell) depressed small, projecting little above the hinge line; anterior end declining somewhat abruptly from the beak; cardinal line and ventral margin gently curved; anterior and posterior muscular impression situated in the upper half of the shell connected by a pallial line.

Formation and Locality. From the valley of Willow river just south of Huron City, Michigan, in yellow sandstone beds of the lower Marshall or middle Waverly. Also found in Licking county, Ohio, in strata of the same age and character. Michigan Geological Survey Collection 19258. Similar forms occur in blue shales. Sp. 19043. Sp. 19106 is in this division also, and is perhaps a rush impression. The extreme abundance of rhynchonelloids reminds one of the zone of *Romingerina julia*, a little higher up.

(4). **Point aux Barques** zone; 85-260 feet below the top of Lower Marshall.

We can distinguish here two or three slightly different faunal stages but as they cannot be certainly distinguished in Winchell's descriptions we are obliged to group them, and there is after all no great difference. Winchell describes a number of Rhynchonellas, Proc. Acad. Nat. Sci., Phil., 1862, pp. 407-409, viz.:

Rhynchonella camerifera, described above and figured here on Plate X, Figs. 11, 12.

RHYNCHONELLA SUBCIRCULARIS, characterized by lack of mesial fold, described as follows:

" n. sp. Shell small, cuneate-rotund, subtumid. Ventral valve, unknown. Dorsal valve with a blunt depressed beak, equalling the hinge, a moderately elevated umbo from which the surface slopes with gentle convexity to the lateral and anterior margins, and abruptly, with slight excavation, toward the superior portion of the rounded hinge-margins. Surface marked by about 32 fine rounded plications, which reach from the margin half way to the beak. Mesial fold wanting. Mesial septum extending one-fifth the length of the shell.

"Length of dorsal valve .25 (100); breadth .259 (100); convexity .08 (34).

"Locality. Grindstone quarries, Point aux Barques, with *R. camerifera*. This species is a close analogue of *R. radialis*, Phillips, sp. Geol. Yorks. 223, Pl. XII, pp. 40, 41, from the Carboniferous limestone of Bollard."

ROMINGERINA [*CENTRONELLA*] *JULIA*, described Proc. Acad. Nat. Sci., 1862, p. 405.

"Centronella julia, n. sp. Shell small, nearly circular, ranging from slightly elongate to transverse, and squarely rounded; both valves with regular lens-like convexity, sometimes with a gentle ridge running the length of the ventral valve, and a slight sinuation near the margin of the dorsal. Ventral valve with a moderate beak, circularly foraminated, turned up at a right angle, covering the beak of its fellow. Area entirely wanting. Shell obsoletely striate concentrically, and having a minutely punctate structure. Apophysary system as follows: A delicate ribbon-like loop, originates from the stout blunt crura of each side of the socket valve, having its flat sides at first vertical; the two branches of the loop proceed at first in lines parallel or a little convergent, and then gradually diverge, widening as they proceed, and assuming an inclined position, until, approaching the front of the valve by a regular curvature, the lower edge has become anterior, giving the band an angle of 30° with the plane of the shell; approaching the median line the band rapidly widens and the front margin is drawn forward in a long acumination, while the inner margin is regularly concave, except that near the median line it turns abruptly forward so as to meet that line at an acute angle. The loop thus forms an urceolate figure on its inner margin, and on the outer a somewhat oval one truncated behind and attenuately acuminate before. In the median line where the two branches meet, both are suddenly deflected downwards, forming a double vertical plate, not quite reaching the ventral valve, the upper edge of which, when viewed from the side, is flatly roof-shaped, while the lower edge describes two convexities, the greater anterior, leaving a notch between them. The surfaces of the loop and median plate are covered with minute, obliquely conical pustules, in some places seeming to become spinulous. The casts exhibit on the ventral side a delicate impressed line extending from the beak to the middle, and on the right and left of this a fainter one; on the dorsal side a median impression with two fainter ones on the right, and two on the left—the median terminating rostrally upon a small pyramidal process (filling the beak of this valve) separated by a short slit (made by the socket ridge) from a smaller isolated process on each side.

"Length, breadth and thickness of an average specimen: .31 (100), .29 (94) and .15 (48)."

Locality. Grindstone quarries, Point aux Barques, in a conglomeritic ferruginous sandstone overlying the gritstones of the Marshall Group, abundant. Figured and assigned to Cryptonella by Hall, Am. J. Sci., XXXV, p. 400, but reclaimed by Winchell in the Proc. Acad. Nat. Sci. Phil., 1865, p. 123, and the figure used again in his Geological Studies. Figured also by Hall, Pal. New York, IV, 1867, p. 419. Pl. 61A. Figs. 41-46; Herrick, Bull. Denison Univ., Vol. III, p. 49, Pl. II, Fig. 5. Made type of this genus and named after State Geologist C. Rominger by Hall and Clarke, "Introduction to study of Brachiopods," Pt. 2, Pl. 52, Figs. 14, 15 and Pal. N. Y., Vol. VIII, Pt. 2, Pl. 79, Figs. 28-30. It occurs with *Camarotœchia Camerifera*, and makes a marked zone, to which belong specimens 19012, 19094, 19092.

PTERINEA CARDINATA (Cf. Sp. 19094). Described Proc. Acad. Nat. Sci. Phila., 1862, p. 412.

"*Pterinea cardinata*, n. sp.—Shell small, hinge line extremely elongate, posteriorly terminating in an angle of 40°, separated by a slight sinuation from the body of the shell; ventral margin transversely semi-elliptic; anterior wing short, saccate; anterior margin forming with dorsal line an angle of about 45°. Beak flattened, not elevated above the hinge; umbonal slope terminating at the middle of the ventral border, opposite which is the greatest width of the shell; descent from the umbonal slope to the antero-ventral border very abrupt. Surface of cast showing numerous faint concentric grooves which are most conspicuous in the postumbonal region.

"Length of hinge .65 in. (100); greatest width of shell .21 (32); convexity of right valve .06 (9); length of anterior wing .06 (9).

"Locality. Grindstone quarry, Point aux Barques, with *Camarotœchia (Rhynchonella) camerifera*, etc.

"This species differs from *P. elongata*, Goldf. (Petref. Germ. i, 135 Taf. CXIX 5), in having a much smaller body, and less distinct from the alate extremities."

MYALINA PTERINÆFORMIS, described same page.

"n. sp. Shell small, equivalve, obliquely elongate, with an alate posterior expansion, which is suddenly thickened above to form the basis of the straight elongated hinge line. Beaks subterminal, obtuse, incurved, elevated a little above the hinge; midumbonal slope making an angle of about 35° with the dorsal margin; from the upper portion the declivity is steep to the hinge on the posterior side, while on the anterior side the shell swells out into a sort of pouch, projecting beyond the beak; posterior margin of shell showing a sinuation just below the hinge, from which a regular curve sweeps around to the anterior side. Shell thin, with fine incremental lines.

"Length of shell along dorsal margin .44 inch (100); length from beak along midumbonal slope .38 (86); distance from beak to anterior extremity .10 (22); to posterior .34 (78); diameter of shell through umbo .12 (24).

"Locality. Point aux Barques, from a friable and ferruginous sandstone overlying the grindstones."

BELLEROPHON GALERICULATUS, Win. Proc. Acad. Nat. Sci. Phila., 1862, p. 426 (also Report 1860, p. 80) described as follows:

"*Bellerophon galericulatus*, n. sp.—Shell, small, globose, involute, ecarinate, exumbilicate, longitudinally striate, and deeply notched. Dorsum broadly and regularly rounded, without any evidences of a band, except in approaching the aperture of adult shells, where a rather broad band with ventrally concave incremental lines can be faintly traced. Aperture crescentic, not suddenly expanded strongly auriculate, with the ears hanging detached from the inner whorl. Notch infundibuliform, deep and broad, obtuse, its sides reaching to the tips of the auriculations. Umbilicus closed, scarcely indented. Dorsal and dorso-lateral surface marked by about 28 longitudinal, sharply raised striæ, separated by much wider flutings, and not perceptibly modified by the dorsal band until within half a whorl of the aperture of the adult shell, when the two middle striæ become slightly raised and enlarged, and the entire set simultaneously die away. Between these striæ and the umbilical point similar striæ diverge spirally and irregularly until intercepted by the former set, or by each other. Cast smooth, perforately umbilicate.

"Average diameter of adult .47 inch (100); height of last whorl at the aperture .26 (55); height of aperture .35 (74); depth of notch .22 (47); width of peripheral belt at notch .06 (13); separating distance between tip of auriculations and inner whorl .10 (21); number of striæ in one-tenth of an inch (ten), and this is the same in young and old specimens. Diameter of largest specimen seen .53.

"Localities. Marshall, Battle Creek, and nearly all other Southern outcrops of the Marshall Sandstone.

"The shell bears a close resemblance to *B. Urei*, of authors, but seems to differ in essential points, as follows: From *B. Urei*, de

Kon. (An. Foss. 356, XXX. 4) in being only half the size, having the dorsal belt elevated instead of compressed, in its very deep notch, less proportional width and distinct auriculations; from McCoy's *B. Urei* (Brit. Pal. Foss. 554) in having the striæ much narrower than the intervening grooves and not at all modified by the dorsal band, and in having the width of the aperture less than the diameter of the shell. Prof. Phillip's figures differ in the absence of auriculations, and in the lateral striæ. To Fleming's original description I have not access."

This form is figured by Herrick, Bull. Denison Univ., Vol. III; p. 89; Pl. II, Fig. 34; Plate IX, Fig. 32.

Above forms all belong in this zone, the locality of other forms are more uncertain, viz.:

CARDIOPSIS MEGAMBONATA, Proc. Acad. Nat. Sci., Phila., 1863, p. 17, 1862, p. 417.

"The specimen here referred is many times larger than the types of the species, being of the size of *C. crenistriata*, Win., from which it differs principally in the coarser and more rigid ribs and more prominent beak.

"The ribs in the Burlington specimens do not increase in number with age, and scarcely increase in size; the intercostal spaces are flat, gradually widening.

"Height from beak to ventral margin .91 inches (100); length .85 (97); thickness of left valve .55 (60).

"*Cardiopsis Megambonata*, n. sp.—Shell very small, ovate, with an elevated little incurved, nearly ventral beak, gibbous umbo and regularly rounded margins, of which the ventral is most abruptly so. Slopes from the umbo convex in all directions to the very margin. Anterior and posterior cardinal margins similar and equal. Surface of casts striately ribbed, most distinctly so toward the ventral border, and in some cases marked by rather strong concentric wrinkles toward the pallial margin.

"Height from beak to ventral margin .25 inch (100); length from posterior to anterior margin .23 (92); convexity of left (?) valve .11 (44).

"Locality. Grindstone quarries, Pt. aux Barques, with *Rhynchonella camerifera*, etc."

RHYNCHONELLA BARQUENSIS, Win. described Proc. Acad. Nat. Sci., Phila., 1862, p. 408, as follows:

"*Rhynchonella Barquensis*, n. sp. Shell small, transversely oval, thin. Ventral valve with a moderately prominent beak and slightly curved cardinal slopes; greatest tumidity near the beak, from which the surface descends in right and left margins. Dorsal valve flattish, most inflated in the middle. Mesial fold and sinus small, traceable one-fifth or sixth the length of the shell, embracing two or three sharp plications, of which the entire surface of each valve receives about 12 or 13. Dental plates of ventral valve parallel; mesial septum of dorsal valve camerated as in *R. camerifera*.

"Length .30 inches (100); breadth .32 (107); thickness .13 (43).

"Locality. Grindstone quarries, Pt. aux Barques, with *R. camerifera.*"

CAMAROTŒCHIA HUBBARDI, Win., Proc. Acad. Nat. Sci., Phila., 1862, p. 407. Described as follows:

"*Rhynchonella Hubbardi*, n. sp.—Shell small, subquadrantal in outline; cardinal slopes straight, forming a right angle or more; lateral extremities about midway of the shell; anterior border gently curved; the two valves equally convex; ventral valve most tumid near the beak, the dorsal in the middle. Surface marked by 21 small rounded radiating plications. Mesial sinus represented by a broad shallow flattening of the mid-frontal slope of the ventral valve, occupying the two middle fourths of its width, and corresponding to 8 or 9 plications. No fold perceptible in the dorsal valve, but a shallow depression extends from the beak about one-third of the length of the shell, corresponding to the extent of the median partition beneath it. Dental plates of the ventral valve well developed, diverging at an angle of about 30°. Shell thin, fibrous.

"Length of a ventral valve .26 inch. (100); breadth .31 (119); convexity, .08 (31).

"Localities. Marshall and the grindstone quarries at Pt. aux Barques, belonging to the Marshall group.

"The dorsal valve greatly resembles that of *R. circularis.*"

SANGUINOLITES BOREALIS, Proc. Acad. Nat. Sci., Phila., 1862, p. 415, thus described:

"*Sanguinolites borealis* n. sp.—Shell rather small, ventricose, transversely elliptic; beak somewhat projecting and incurved, less than one-fifth the shell length from the anterior extremity, with a lunuliform excavation in front of it; dorsal margin straight, ventral margin slightly arcuate; posterior extremity regularly rounded; anterior sharply bent in front of the lunulae, from which it slopes with a truncate backward curve to the ventral border; umbonal slope extending diagonally to the infero-posterior margin, somewhat angulated behind the beak, and inflected toward the cardinal region. Surface of shell of northern specimens unknown; cast showing several distinct concentric grooves. Shell of southern specimens thin, marked both with concentric and minute radiating striæ. Greatest height of shell along the perpendicular from the beak; greatest convexity in the middle of the same line.

"Length 1.10 inch. (100); breadth .44 (40); thickness of right valve .15 (44).

"Locality. Grindstone quarries, Pt. aux Barques above the gritstones, and Moscow, Hillsdale county.

"Distinguished from *S. unioniformis* and *S. Marshallensis* by its terminal beaks, greater relative gibbosity, greater length and its posterior attenuation."

We identify this species somewhat doubtfully with the form figured in Plate XI, Fig. 11, which, however, comes from a higher horizon.

BELLEROPHON BARQUENSIS, Proc. Acad. Nat. Sci., Phila., 1862, p. 427, described as follows:

" n. sp. Shell small, globose, involute, rapidly enlarging, dorsally depressed; umbilicus small, but deep; dorsal broadly convex, with a distinct raised band; sides sharply rounded into the umbilicus; aperture crescentic, expanded with a deep broad construction behind it, notch deep and narrow. Surface marked by fine, regular, longitudinal lines, which cover the band as well as the other parts. Diameter .48 inch. (100); transverse diameter of aperture .54 (112); height of aperture to middle of umbilicus .27 (56).

"Locality. Pt. aux Barques, above the gritstones.

"Most nearly resembles *B. Michiganensis*, but the apertural construction and single set of striae render it easily distinguishable."

It is quite likely that Winchell assigned the form here described at first to *B. galericulatus* as in his latest list he does not mention *B. galericulatus* from northern Michigan.

(*Dentalium barquense*, Proc. Acad. Nat. Sci., Phila., 1862, p. 425, 1865, p. 131 is of uncertain affinities and should be expunged.)

(*Sanguinolites strigatus*, Proc. Acad. Nat. Sci., 1865, p. 129, was undescribed, and specimen lost and should be expunged.)

Lepidodendron, Proc. Acad. Nat. Sci., Phila., p. 387, 1870, mentioned but not described.

Productus concentricus, Proc. Acad. Nat. Sci., Phil., 1862, p. 411, fragments only of a productid from the grindstone quarries which may not be this species, and were not described. We have also Productus fragments from the *Romingerina julia* zone, Sp. 19094.

Chonetes illinoisensis smaller than typical, Proc. Acad. Nat. Sci., Phil., 1863, p. 5; 1865, p. 116.

[*CTENODONTA*] *(NUCULA) SECTORALIS*, Proc. Acad. Nat. Sci., Phil., 1862, p. 418, described at first as Nucula, and corrected, Proc. Acad. Nat. Sci., Phil., 1865, p. 129, but now all the Ctenodontas are referred to Nucula.

" n, sp.—Shell rather small, ventricose, sectoriform, with nearly central beaks. Anterior cardinal slope straight; posterior, nearly so, making with the former an angle of 88° to 91°; ventral border subcircular. Beaks prominent, acute, direct, incurved. Anterior hinge plate with about 17 teeth; posterior with about 13, much smaller. Adductor scars subterminal, profound, roundly, oval. Surface of casts perfectly smooth.

"Length .86 inch. (100); height .74 (86); thickness .44 (51); distance from beak to line joining extremities .40 (46); length of anterior end .51 (59); of posterior end .35 (41).

"Locality. Battle Creek and Grindstone Quarries, Point aux Barques."

NUCULA STELLA, Proc. Acad. Nat. Sci. Phila., 1862, p. 419, abundant in the lower peanut conglomerate, Sp. 19032, with *Nuculania bellistriata*, described thus:

"n. sp. Shell very small, elliptic-ovate, with subcentral beaks. Anterior cardinal slope arched, posterior nearly straight, extremities rather sharply rounded; ventral side semi-elliptic. Anterior hinge plate with 17 minute, acute teeth; posterior with 5, angulated in both cases towards the beak. Beaks a little attenuated near the extremity, curved inwards and backwards. Pallial line entire, connecting the muscular scars, which are oval, and situated considerably above the middle line of the shell. Shell thin, with delicate concentric striæ.

"Length .33 inch. (100); height .24 (73); thickness .14 (42); length of anterior end .20 (61); of posterior end .13 (39); distance from beak to line adjoining extremities .14 (42); length of anterior end .20 (61); of posterior end .13 (39); distance from beak to line adjoining extremities .14 (42).

"Locality. At every outcrop of the formation in the southern part of the state. Also at the Grindstone Quarries, Point aux Barques.

"This beautiful little shell has affinities with *N. ventricosa*, Hall, (Iowa Rep., 716, Pl. 29, Fig. 4), from the coal measures of Iowa. It is easily mistaken for the young of *N. hubbardi*, but is proved distinct by its more rounded sides and fewer teeth, as well as by its occurrence in a region of the state where the larger species is as yet unknown."

CYTHERE CRASSIMARGINATA, Proc. Acad. Nat. Sci. Phila., 1862, p. 429, thus described.

"*Cythere Crassimarginata*, n. sp. Carapace minute, ventricose, regularly oval, microscopically wrinkled—scrobiculate; hinge line impressed, and hinge margin a little hollowed; valves margined by a smooth bead, which projects slightly beyond the general surface, behind which is a small groove; cast smooth, but margined by a raised band terminating near the hinge anteriorly and posteriorly.

"Length .08 inch; breadth .05.

"Localities. In the Marshall Sandstone, at Battle Creek, Liberty (Jackson county), Moscow, near Napoleon and at the Gritstone Quarries, at Point aux Barques, with *Rhynchonella camerifera*."

Also near Wheatfield. Cooper has noticed them.

"Beside the species already enumerated from the Marshall group there yet remain a few too imperfect for adequate description, or belonging to classes not yet investigated. Among these are Lepidodendron and Neuropteris?; a coralline structure, like Fistulipora encrusting foliaceous or branching, with minute, short, crowded polygonal cells .0088 of an inch in diameter, without visible lamellæ, but with some indications of transverse floors; some undetermined Lamellibranchs; two sorts of Chiton-like scales; two or three Nautili, of which one is nodulous; and sundry remains of spines, teeth and bones of fishes."

Munsteroceras [*Goniatites*] *oweni*, Cf. Win. Am. J. Sci. XXXIII, 364, Sp. 19014; we can recognize this form probably, as well as other species of Goniatities in the fargments from the Grindstone quarries. They seem to have been originally beach broken fragments, and are at times right in the overlying conglomate (Sp. 19017), and also in nodules in the sandstone (Sps. 19014-19016).

Goniatites propinquas and—

Goniatites shumardianus, described in the same article, all are forms like his, with simpler sutures than occur higher up in the series.

Orodus a genus of fish, and—

Calamites, a rush, are added by Rominger.

From our collections we may add:

Orthoceras, two species, Sp. 19033 from the lower peanut conglomerate is a large form; Orthoceras, Sp. 19014, has marked rings about 8 to 1 inch.

Crinoid stems, are abundant in certain layers, and two, or more species are represented. Some of the stems are very large.

Pleurotomaria? Sp. 19014. Fragment.

Spirifer, Sp. 19014 a small depressed form.

Ctenacanthus? Sp. 19013 and 19014. These hollow spines have the rear angles much sharper than any species I know.

Principal cusp of a shark's tooth, Sp. 19016. Cf. Orodus. The teeth known as Orodus and the spines as Ctenacanthus have been supposed to belong to the same fish.

Melonites is reported by Geo. H. Girty.

As we go up toward the Point aux Barques sandstone fossils become scarcer, and yet no essential change in the character of the fauna is noticed. Rominger recognized the cast of a Rhynchonella, and an impression of a Goniatite right under the Point aux Barques sandstone. Of the fauna between the Point aux Barques sandstone and Flat Rock we know little.

One specimen, 19204, not absolutely in place shows *Schizodus*, or *Posidonomya*, and coaly bits of vegetation.

Almost directly beneath the heavy beds of Flat Rock Point (Point au Pain Sucre), comes a peanut conglomerate, and ripple marked beds, with traces of rushes, a Goniatite, Sp. 19016, and as Rominger remarks (Vol. III, p. 71), *Camarotœchia camerifera*.

Somewhat uncertain as to their exact position in the column, and not assuredly in place are: Sp. 19089, a coarse, friable, very red sandstone containing—Productus, *Orthis michelini*, and a Merista or Cryptonella-like form. Sp. 19090 which appears to be just about the horizon of the Port Austin sandstone, and is a very similar rock to 19089, and beside the same Merista form (cf. *Athyris ohioensis*), apparently contains a Schizodus and *Crenipecten caroli*, gastropods and Rhynchonella, but the fossils in these red sandstones drop to pieces as you look at them, and to get the best results should be studied thoroughly by a competent palæontologist upon the ground. Mr. Cooper has not visited them.

Taking this fauna as a whole, we may notice as characteristic the abundance of rhynchonelloids, and fish fragments and coaly remains. Many of the specimens, especially the Goniatites, and fish remains, are evidently beach worn and broken. It is distinctly littoral. Compared with the Lighthouse Point fauna the smaller size,—forms is noticeable. Comparing with the fauna next following the comparative simplicity of the sutures of the Goniatites, like those of *Munsteroceras oweni* rather than those of *Goniatites lyoni* is noticeable. The Goniatites are too fragmentary to lend themselves to reproduction, and the fish teeth and spines hardly characteristic enough.

(5.) **Hardwood Point Zone,** 85 feet below top of Lower Marshall.

Immediately above Flat Rock Point, immediately to the southeast on a 14 foot terrace, and traceable to the water's edge at the southwest corner of Sec. 24, T. 19 N., R. 12 E., we find beds abundantly fossiliferous and easily recognizable. The most striking feature is perhaps the abundance of Solen forms, of which we have hitherto seen only traces, and bryozoa. In the lowest horizon immediately over the Flat Rock sandstone, from which we find previous mention only of a "Cypris like shell* we obtained Fenestella, Sp. 19428, Crinoid buttons," *Solen quadrangularis*, Rhynchonella, traces of Goniatites, *Nuculana*, cf. *Nuculana similis*, Ohio, VII, 17, and about the same size. Cf. *N. bellistriata?* or *N. diversa* or some form markedly produced at rear. We find above some blue not so fossiliferous micaceous shales with even here bits of rushes, and Goniatites, faintly impressed, and borings or burrows of mollusks like Nucula or

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*Winchell's report, 1860; p. 80.

Nuculana, Sp. 19132, and Sp. 19032. A little higher at Hardwood Point we find a calcareous band rich in fossils, from which Winchell enumerates:

ORTHOCERAS INDIANENSE, Hall Cf. Am. J. S., Vol. XXXIII, p. 354. Cf. *O. cinctum* or *O. goldfussaneum.* Winchell's description is as follows:

"Septate portion of shell more than 3.75 inches in length; inclination of sides forming an apical angle which varies in different specimens from 6° to 11°; transverse section circular; septa at right angles with the central siphon; ratio of depth of chamber to its diameter, in different specimens 2-0, 2.67, 2.71 and 3.46; ratio of concavity of septum to its diameter 2.81; ratio of diameter of siphon to diameter of shell 5.67. No surface marks discernible on the cast.

"Localities. The most abundant Orthoceras in the Marshall sandstone. I have specimens from Marshall, Calhoun county, Holland, Ottawa county, Moscow and various other points in Hillsdale county, and from Hardwood Point (one mile S. W. of Point au Pain Sucre) on the shore of Saginaw Bay in Huron county.

"The specimens from Michigan exhibit all the characters published of *O. Indianensis* Hall, except the apertural constriction, with reference to which I have not been able to make any observations. The casts of these species cannot be distinguished from those of *O. cinctum* Sowerby, as defined by de Koninck ("Animaux Fossiles," p. 513, Pl. XLIII, Fig. 6; XLIV, 5; XLVIII, 3). It is equally indistinguishable from *O. Goldfussanum* de Kon. (pp. cit., 510; Pl. XLIII, 3, 4), except that the septa of this species are separated by only one-eighth of their diameter."

ORTHOCERAS CLINOCAMERATUM, Win.; in Am. J. Sci., XXXIII, p. 356 described as follows:

"The only specimen of this quite distinct form is only 1½ inches in length, partly septate. It is a fragment of a shell about 3.3 inches long, having a major apical angle of 11°. The section is elliptical, with the minor axis to the major as .24: .45 = 1.88. The first two septa are .08 apart, and the relation of this interval to the larger diameter at the same point is 6.25. The septa are deeply concave, oblique, and slightly sinuous, having one side .12 in. in advance of the other. The greater diameter of the specimen is .7 in. at one end and .45 in. at the other.

"Locality. In the Marshall sandstone at Hardwood Point, one mile S. W. of Point au Pain Sucre, [Called also Flat Rock Point] on the shore of Saginaw Bay."

Compare our specimens 19143, and 19011, 19136, 18118; the forms of Orthoceras seem to be on an average a little smaller than those below.

Cyrtoceras tesselatum, doubtfully mentioned from a small fragment.

GONIATITES MARSHALLENSIS, Am. J. S. Win., Vol. XXXIII, p. 362, described as follows:

"Shell rather long, consisting of at least four whorls, the inner moderately impressed into the outer; transverse section varying from an ellipse of small excentricity to an oblong figure, surface smooth. Aperture and outer chamber not seen. Septa close, the lobes also reaching the next posterior saddles. Dorsal lobe twice as long as its greatest width, clavate, with a long cuspidate acumination, at the extremity of which can sometimes be seen the outline of the minute siphon; first and second lateral lobes similar to the dorsal in form, but successively a little smaller and not acuminate; accessory lobe obtuse, half the size of the second lateral; ventral lobe profound. Dorsal and lateral saddles of form similar to the principal lobes, but regularly rounded at the extremity; first accessory saddle, half the size, the second, imperfectly developed.

"Diameter of largest specimen seen 1.75 (100); major axis of transverse section .59 (34); minor axis .47 (27); length of dorsal lobe .26 (15), of which the cusp is about .07 (4); greatest breadth .12 (7). Diameter of siphon .015 (0.9).

"Localities. The most abundant Goniatite in the feebly cemented, ferruginous sandstone at Marshall. Found also in a similar rock at Moscow, and numerous other localities in Hillsdale and Jackson counties. It occurs in the hard bluish calcareous sandstone at Battle Creek and in the hard purple sandstone at Hardwood Point, Saginaw Bay.

"This Goniatite belongs to the group which embraces *G. Henslowi* Sow, *G. serpentinus*, *cyclolobus* and *mixolobus* of Phillips, but after careful study it seems sufficiently distinct from all. Its closest European analogue is *G. mixolobus* Phil., from the Mountain limestone of the Isle of Wight and the "Posidonomyenschiefer" of Wiesbaden. Its nearest American analogue seems to be *G. Lyoni* Meek and Worthen, (Proc. Acad. Nat. Sci. Phil., Oct., 1860), with which Prof. Hall's *G. Hyas* is identical (See 13th Rep. Regents N. Y., p. 102). The Michigan species, however, differs from the Rockford one in the addition of an accessory lobe and saddle, and in the dorsal lobe being broader and relatively longer. It is also somewhat more involute."

Our specimens, Sp. 19113, 19011, 19137 have a suture much like *Goniatites lyoni*, but with one denticle on a number of the lobes, i. e., an approximation to Ceratites. This is not clearly indicated in Winchell's description but is shown in his specimens and drawings. To these forms we add from the 1860 report, p. 80, Nucula, which Rominger says is *Nucula hubbardi*, i. e.,

Palæoncilo sulcatina, Proc. Acad. Nat. Sci. Phil., 1862, p. 418 and 1865, p. 128. Sp. 19011; Sp. 19140 shows muscle scar and pallial line, slightly sinuate. This has been frequently figured, by Conrad, Hall and Herrick.

Solen quadrangularis, Win. Proc. Nat. Sci., 1862, p. 422, an abundant and characteristic form often in purple micaceous shales. Sp. 19010, 19028, 19136.

(*Clymenia?* Cf. pp. 85 and 86). As no Clymeniæ are returned from the Marshall in Winchell's final list, he undoubtedly concluded to refer the forms in question to the Goniatites.

Beside the forms mentioned by Winchell, Rominger adds *Rhynchonella* and *Productus*. We may add a variety of fish remains, to wit: Sp. 19011, 19023 shark spines in considerable variety, cf. Acanthaspis;

Fish teeth; as in the grindstone beds there are often small black rounded fish teeth, but occasionally we have something better, e. g. *Cladodus (concinnus?)* Sp. 19139, very well preserved, one large, four small cusps, two on each side, the outer larger.

Psammodus or cf. *cochliodus*, a large pavement tooth, Sp. 19133 *Ganoid* scales, Sp. 19027.

Conularia, Sp. 19109, cf. 19146, a mere fragment.

NUCULITES FALLAX, n. sp. Cooper, Plate XI, Fig. 4. Sp. 19259.

Shell, small, elongate, ovate, width equal to three-eighths the greatest length of the shell, cardinal and ventral line equi-distant for the greatest length of the shell, anterior end truncate, posterior portion of the shell meeting the ventral margin at the end of the umbonal ridge where it is abruptly rounded; beak depressed anteriorly, about one-tenth distant from the end of the shell, clavicle extending ventrally marked with imperfectly preserved concentric markings. Teeth not shown in any specimen yet found.

Formation and Locality.—In the lower Marshall along the shoreline just west of Port Austin, Huron County.

SANGUINOLITES MICHIGANENSIS, Herrick. Figured here Plate XI, Figs. 12, 13, Sp. 19283, 19284.

1888. *Sanguinolites Michiganensis*, Herrick or Winchell. Bull. Denison Univ., Ohio, Vol. III, p. 70, Pl. 7, Fig. 10.

Shell quadrangular, ovate, dorsal and ventral lines subparallel, posterior end slightly large. Beaks one-fourth distant from the anterior end, slightly appressed, not projecting beyond the hinge line. Umbonal ridge well defined, extending to the abruptly rounded posterior ventral margin. Umbonal slope slightly concave dorsally, having a well defined depression extending from the middle of the ventral margin towards the beak. Anterior end abruptly rounded, with a well marked lunule on the dorsal part. This species was identified by Alexander Winchell at the time the Ohio specimens were being studied as his *S. Michiganensis*, but no description or figure from him is extant. The species was figured by Prof. C. L. Herrick without any definition.

"Formation and Locality. From the Marshall or upper Waverly immediately west of Port Austin."

SANGUINOLITES BOREALIS? Winchell. (Plate XI, Fig. 11, Sp. 19282.)

1862. *Sanguinolites borealis.* Winchell, Proc. Acad. Nat. Sci., Philadelphia, p. 415.

"Shell rather small, ventricose, transversely elliptic; beak somewhat projecting and incurved, less than one-fifth the shell length from the anterior extremity, with a lunuliform excavation in front of it; dorsal margin straight; ventral margin slightly arcuate; posterior extremity regularly rounded; anterior sharply bent in front of the lunule, from which it slopes with a truncate backward curve to the ventral border; umbonal slope extending diagonally to the infero-posterior margin, somewhat angulated behind the beak, and inflected toward the cardinal region. Surface of shell of northern specimens unknown; cast showing several distinct concentric grooves. Shell of southern specimens thin, marked both with concentric and minute radiating striae. Greatest height of shell along the perpendicular from the beak; greatest convexity in the middle of the same line.

"Length (in inches) 1.10 (100); breadth .44 (40); thickness of right valve .15 (44)."

"Locality. Grindstone quarries, Pt. aux Barques above the gritstones and Moscow, Hillsdale county. The specimen here illustrated is from Hardwood Point, Huron county, Michigan, where it was found in red, friable, ferruginous sandstone."

Michigan Geological Survey Collection, number 19282.

Leaving Hardwood Point and going southeast after passing a relatively massive sandstone we come to a fossiliferous shingle, and on the bluff of the Algonquin terrace, which the Port Austin-Port Crescent road skirts, we find rock exposed, only certain narrow belts being fossiliferous; similar beds occur on Sec. 2, and on the hill of Sec. 31, adjacent, with fauna so much alike as to make them essentially one horizon. Sp. 19112-19128, 19140-19143, 19145, 19279.

From them we have:

Ganoid scales, rhomboid diagonally wrinkled, Sp. 19117.

Goniatites marshallensis, as mentioned; also Sp. 19117, 19113, 19128,

Goniatites allei? Sp. 19142, 19113, 19126, 19127, 19140, a fragment.

Orthoceras indianense or multicinctum?, 19118, Sp. 19143.

Fenestella, Sp. 19121.

Bellerophon, cf. *B. nautiloides* or *B. galericulatus*; Sp. 19113, 19140, 19141.

Characteristic of these beds in a wealth of lamellibranchs, especially pterinoid forms, inclined, with a straight hinge line, e. g., *Leiopteria torreyi* cf. *ortoni*, Ohio, VII, Pl. XXIV, Figs. 1, 8, 9, 10, 11, 12. If recognized by Winchell it was probably as a Pterinea or as *Myalina Pterinaeformis*. The forms are about the size of Herrick's Fig. 10; cf..*Anthracoptera elongata* Q. J. G. S., 1893, XLIX, Pl. VII, Fig. 16. Sp. 19114, 19127, 19128, 19145.

LEIOPTERIA TORREYI? Hall. (Plate XI, Fig. 2).

1884. Hall. Pal. New York, Vol. V, Part I, Pl. I., p. 174.

This species which is described by James Hall from the sandstone and conglomerate of the Chemung group at Panama, N. Y., is defined as follows:

> "Shell of medium size, rhomboidal, sub-falcate; body narrow ovate, arcuate, oblique at an angle of less than 45° with the hinge, height equal to about two-thirds of the length; anterior and basal margins broadly curving from the byssal sinus; post basal margin produced and abruptly recurved.
>
> "Left valve very convex, gibbous in the middle and above. Right valve unknown.
>
> "Hinge line straight, about equal to the height of the valve. Beak sub-anterior, directed forward, acute, prominent and arching over the hinge. Umbonal region narrow, ventricose, well-defined, subtending an acute angle.
>
> "Ear large, bending downward, marked by a strong oblique fold, limited by a broad, vertical byssal depression and shallow sinus margin convex; extremity apparently obtuse. Wing joining the body above the posterior extremity, limited by the nearly verticle post-umbonal slope which makes a more or less marked sulcus; margin concave; extremity produced, acute.
>
> "Surface marked by a fine striæ of growth which are somewhat regularly lamellose on the body of the valve.
>
> "A left valve has a length of 29, height 22, hinge line 21."

Formation and Locality. From the Marshall group along the Port Crescent road immediately west of Port Austin, Huron county, Michigan.

Nuculana, cf. bellistriata. Sp. 19125 ill preserved.

Nuculites fallax, as described above.

PALÆONEILO SULCATINA, Sp. 19140, 19141, shows the posterior muscle scar and slightly sinuate pallial line.

Sp. 19145 is concentrically striated and very much like Winchell's forms, *Sanguinolites* (*Cardinia, Inoceramus*) *concentricus*, but traces of ligamental pits on a straight hinge line make the genus much more akin to Inoceramus; cf. also *Sanguinolites amygdalinus*.

The usual state of preservation of these fossils is in yellow fragile casts in a bluish to purplish impure sandy matrix. It will be noticed that the fauna of these upper beds, is (with the exception of some lamellibranchs), practically the same as that of Hardwood Point. Taking the two together they differ unmistakably from the fauna below the Port Austin sandstone by the replacement of brachiopods by lamellibranchs and the more complex sutures of the Goniatites.

From the Lighthouse Point beds to the top of these upper beds is (260 + 176) some 436 feet, with two considerable sandstone belts, perhaps three or four, included. Yet if we compare our fauna with those of Herrick's zones we find that though the Lighthouse Point section seems to correspond decidedly better with the Waverly freestone, than any lower horizon, on the other hand the upper beds also find their nearest analogues in the same stratum. So that either the Waverly freestone corresponds to a much larger series of deposits in Michigan, or the fauna lasted much longer in Michigan, see below p. 288, or two faunas consecutive in Michigan were migrating so as to meet and be contemporaneous in Ohio. In that case we might suggest that the brachiopods, Syringothyris, Rhynchonella, and Spirifer, and Romingerina were moving southwest while the solens and aviculoids came north. The generally smaller character of the upper faunas in Michigan suggests that in some way the conditions were becoming more unfavorable to life, a supposition in entire accordance with the fact that hitherto the out-crops of the Upper Marshall or Napoleon have proved unfossiliferous.* Finally the fauna of Marshall and Battle Creek, seems as already stated by Winchell to correspond to the upper zones of our section.

Ohio correlations

by W. F. Cooper.

The correlation with the Ohio is as follows:†

To Prof. C. L. Herrick, President of the State University, Albuquerque, New Mexico, I am especially indebted for favors which have always been extended, and through which this work has been begun.

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*See Rominger III, p. 88.

†From this point to the end of the section is solely by W. F. Cooper and expresses his views.

The lower Carboniferous of Michigan, beginning at the bottom, has been separated into the Bedford shale, Berea grit, Berea shale, Coldwater (Cuyahoga in part) shales, lower Marshall sandstones, Napoleon or upper Marshall, Michigan series, and Bayport (Maxville) limestone.

In Ohio the same strata are represented by the Waverly formation, which with some modifications from the reports of Professor C. L. Herrick and Dr. Edward Orton, may be divided into the Bedford shale, Berea grit, Berea shale, Buena Vista flags, Cuyahoga shales, Raccoon shales and sandstones, and conglomerate I; the middle Waverly or lower Logan, conglomerate II; the upper Logan or Burlington and Keokuk and Maxville.

The Bedford shale which forms the lowest member of this series has in southern Michigan a thickness of fifty feet in places, according to the records of the well borings (Geol. Surv. of Mich., Vol. V., Pt. II). In Ohio the horizon extends in its line of outcrop from Pennsylvania west and south as far as the Ohio river, and doubtless beyond into Kentucky. It contains a recurrent fauna with a Hamilton facies. Some of the characteristic New York Hamilton species which are found in Ohio are: *Orthis vanuxemi*, *Chonetes scitulus*, *Ambocoelia umbonata*, *Macrodon hamiltonae* and *Cypricardella bellistriata*. In northwestern Pennsylvania these strata are said to be represented by the Cussewago shales.

In Huron county, Michigan, the Bedford shale is succeeded by the Berea grit, which serves very well as a datum plane as is shown elsewhere in this report. In Ohio the Berea grit varies considerably in thickness, being anywhere from five to one hundred and fifty feet thick. In the upper layers it exhibits a tendency to become flaggy and more fossiliferous. *Atrypa reticularis* and *Leptaena rhomboidalis*, together with several other species of a local fauna, have been found in the flags of Delaware county, Ohio. In Pennsylvania it has been identified with the Corry sandstone. The Berea shale is immediately over the Berea sandstone. In Huron county, Michigan, it is easily traced in the well borings and has an average thickness of 115 feet while in the southern part of the state it is in places only twenty-five feet thick. This horizon which has also been called the Waverly black shale, by Andrews, varies in Ohio from 15 to 50 feet in thickness, throughout the line of outcrop, and is an exceedingly persistent and well defined horizon. In northeastern Ohio, near the Pennsylvania line, it lies immediately under the Carboniferous millstone grit; a fact of importance in the development of the lower Carboniferous of that state, which has heretofore been misunderstood.

Lying upon this horizon are the Buena Vista flags which are deserving of recognition as a horizon separable from the Cuyahoga shales above. The Dictyophyton, Producti, and *Atrypa reticularis*, which are found in them, apparently sustain the same relation to the Chemung of New York as does the Bedford to the Hamilton of that state. They are extensively quarried at Buena Vista on the Ohio river. Northward they extend into the valley of the Cuyahoga river and to the east as far as Warren county, perhaps farther. In Michigan their position has not been determined as yet, but they will probably be found south of Harbor Beach or White Rock along the lake shore.

The Cuyahoga shales vary in lithological character, throughout any one continuous section, but can, within certain limits, be distinguished by a dark blue nodular shale which very often contains fossils exquisitely preserved. These fossils may be found at Coldwater in Branch county and in less limited numbers at Rock Falls near Harbor Beach, Huron county, along the lake shore. The same nodules are found forty feet below the Carboniferous conglomerate at Cuyahoga falls, at Moot's run in Licking county nearly 225 feet below the same horizon, and at the level of the Ohio river at Sciotoville nearly 200 feet below the coal measures. There are sections in Warren county, Ohio, where this horizon is absent. Judging from the gradually extending shore line southward on which the later zones in part were deposited it is probable that the elevation of the strata had then begun in Warren county before the deposition of these beds.

This zone which is embraced in the Coldwater series of Michigan is 200 feet thick more or less in the southern part of the state. In Huron county it is difficult to draw the line between the horizons below and above these strata. The top of the beds outcropping near Harbor Beach must be about 1200 feet below the Coal Measures, while the top of the Berea shale is given by Dr. Lane from the well records as 500 feet lower at that locality which measures the approximate thickness of the zone. I think it probable, however, that a portion of the lower part of these strata may be included in the

Buena Vista horizon. There is south of Harbor Beach at the mouth of Allen creek a section at Rock Falls where I collected *Chonetes scitulus, Productus shumardianus, Productus newberryi,* var. *annosus, Streblopteria media, Conularia gracilis,* and *Phaethonides spinosus.*

These forms are also found in the Cuyahoga in Ohio. Lithologically and palæontologically this outcrop is more closely paralleled by the exposures which occur in Licking county than in the northern portion of the state in the valley of the Cuyahoga river. There is cumulative evidence to indicate that the strata of this zone were laid down in a basin rather limited to the eastward in central Ohio; which existed before the Cincinnati anticline had developed, and which may have obtained its sediment from the northward. At Moot's run, Licking county the Cuyahoga is represented by a series of light blue flags containing concretions and a *Chonetes scitulus* in the greatest numbers, which are overlain by a shale which contains nodules often with perfectly preserved fossils. The section at Rock Falls is identical in character, superposition and habitat which can hardly be accidental when taken in connection with its relative position. The same strata at Coldwater I have not yet had an opportunity to study fully.

The Waverly shale, which is a term Professor C. L. Herrick has given to the upper 40 or 50 feet of the lower Waverly or division I is rather apt to be confusing as thus limited. I have adopted the name Raccoon shales which was earlier used by L. E. Hicks to include all the strata between the middle Waverly or Lower Logan and the Ohio black shale, for this particular zone, which is the uppermost part of his series. A typical outcrop is found on Raccoon creek half way between Granville and Newark, Ohio, where no less than thirty species have been collected, most of which are confined to these beds. Over two-thirds of the number are lamellibranchs. Some of the characteristic species are: *Palæoneilo concentrica, P. attenuata, Sanguinolites flavius,* and *Sanguinolites unioniformis.* North of Licking county this formation thins out about half way between Wooster and Lodi, Ohio. In Michigan I have been unable to correlate it in Huron county, but stratigraphically and lithologically it corresponds to the 196 feet of strata outcropping below the conglomerate at Point aux Barques lighthouse and southward almost to Harbor Beach. In Hillsdale county and at Verona mills near Battle Creek the same layers are apparently represented by a coarse grained, yellowish, somewhat friable sandstone which contains in great abundance *Palæoneilo concentrica* and *P. attenuata*. At Waverly junction, near Holland in Ottawa county, the same strata are extensively quarried. At that place over 35 feet of rock are exposed which is abundantly fossiliferous, almost all the species being lamellibranchs. *Sanguinolites flavius*, *Palæoneilo concentrica*, *P. attenuata*, *Nucula iowaensis*, *Nuculana similis*, *Athyris lamellosa*, and *Bellerophon galericulatus* were the only species identified which are characteristic of the Raccoon shales in the Ohio basin. The almost entire absence of brachiopods rather tends to emphasize the relationship, but the cephalopods are relatively much more abundant than in Ohio.

We have, separating the lower Waverly from the middle Waverly or lower Logan, a band of conglomerate which varies considerably in thickness and which extends in variously modified phases from southern Ohio to Point aux Barques lighthouse. In Licking county it is well exposed in the bed of a small "run," in a quarry about one mile south of Newark, Ohio; at the "dug way" three miles west of Newark; and at Wooster, Ohio, immediately north of the city on Christmas run; and on the shore of Lake Huron at Point aux Barques lighthouse. (See fig. 5.) It is not found in the valley of the Cuyahoga river which was elevated before the formation of this bed. In otherwise continuous sections north of Wooster and south of Burbank the Cuyahoga shale lies immediately underneath conglomerate. I. In this connection it may be well to notice the observation of A. C. Lane that in the conglomerate at Point aux Barques lighthouse rounded pebbles of a black shale were found which could hardly have come elsewhere than from the Devonian black shale. The deposition of this bed must have been a time of important geologic action. In Ohio nearly all of the species became extinct as the result of the change of environment, and but few forms are found in the horizon in question, so that its correlation rests to a large extent on stratigraphical and faunal relations. For in the underlying shales and sandstones the fauna is largely lamellibranch, almost entirely so in point of numbers; in the conglomerate it consists altogether of brachiopods. *Spirifer deltoideus* is one of these characteristic species which occurs in Ohio and in Michigan along with several peculiar brachiopod species which are not found in the Ohio basin. There is evidence to indicate that this bed was in Ohio deposited by river action coming from the north or north-westward.

The lower Logan or middle Waverly, the "quarry rock" of Central Ohio, is represented in sections from the Ohio river to Burbank; in Michigan from the Point aux Barques lighthouse to the *Romingerina julia* stratum west of Grindstone City. In the southern and central part of Ohio it is 40 feet in thickness on the average, while in a quarry northwest of Wooster it is 60 feet thick. In Michigan the series which is in part a representative of the Marshall exposed in Calhoun county and the upper Kalamazoo valley is made up of grits, sandstones, conglomerates and shales with an abundant fauna. The thickness of this division which should be made to extend from the Point aux Barques lighthouse to the *Romingerina julia* layer west of Grindstone City, and perhaps the 20 feet of strata resting upon it, is approximately 215 feet in thickness and includes the lower 40 feet or so of the Marshall as defined by Winchell. At Point aux Barques lighthouse the horizon is 935 feet and more below the Bayport or Maxville limestone as exposed on Wild Fowl Bay northeast of Bay City. Within this greatly increased thickness of sedimentation there are at least four horizons each with their characteristic fauna.

Thirty or forty feet below the top of the series as it has here been limited we have a layer which outcrops along the roadside leading to Port Austin, and on the old lake shore line west of Grindstone City. In it occur *Romingerinà julia* and *Camarotœchia camerifera* in the greatest abundance, in places making up the entire stratum. On Sec. 17 in the valley of the Willow river the layer again outcrops. At this locality the specimens are better preserved, while *Romingerina julia* is relatively more abundant. These species are distinctive of the lower Logan in central Ohio, and while it is impossible to demonstrate the same relationship here, there is evidence when taken in conjunction with the underlying beds that they form an integral part of this series and of the middle Waverly in general. About 15 feet below are the fine grained and uniform blue grits which make the famous Huron county grindstones. In and near these grits occur a great variety of fossils, especially of cephalopods which afford little data for comparison. Some of the species which are found there and admit of identification in the "quarry rocks" of central Ohio, are: *Syringothyris carteri*, *Edmondia* *burlingtonensis* and *Goniatites lyoni.* Incidentally it might be observed that these species are considered by some authors as characteristic of the Kinderhook beds of Illinois. The lower bed of "peanut conglomerate" exposed just west of the gristmill at Grindstone City is characteristically full of *Nuculana bellistriata,* a form which has not yet been found in Ohio. If we continue along the coast to Point aux Barques lighthouse we find overlying the conglomerate, streaks of sandstone imbedded in the shale and filled with a great variety of fossils, from which both Rominger and Winchell have mentioned many species, and which will undoubtedly yield more material to any one who will take the pains to work them up. From this bed we have collected many species which are more distinctly Carboniferous in character than those from the Cuyahoga strata farther south. Lithologically the formation both here and in the valley of Willow River is typically lower Logan, faunally the species which are here given may be considered typical of the same horizon along with some species which have not yet been identified in Ohio. Of the former we have identified the following forms: *Syringothyris carteri, Camarotœchia sageriana, Cryptonella eudora, Crenipecten winchelli,?* *Sanguinolites naiadiformis, Schizodus triangularis, Bellerophon cyrtolites, Pleurotomaria strigellatta* and *Proetus missouriensis.* To these characteristic species may be added *Derbya crassa, Spirifer centronatus, Spirifer huronensis, Eumetria polypleura, Palæoneilo marshallensis, Leiopteria halli ?* and many other forms which are in part generally distributed throughout the lower Carboniferous in Ohio, along with others not yet found in that region.

Extending from the beds at Flat Rock Point west of Port Austin to the heavy bedded dark sandy flags overlying the *Romingerina julia* layer west of Grindstone City we have 110 feet of strata which are almost barren of fossil remains. These layers which are embraced in the lower Marshall have their base 200 feet below the top of the lower Marshall and 40 feet or less above the *Romingerina julia* zone. I have placed the base at this point only on account of the negative evidence afforded by the almost entire absence of organic remains, together with the physical and geographical changes which occurred at the time of the deposition of its beds.

The base of this series consists of flags succeeded by about eighteen feet of massive white sandstone at Point aux Barques hotel. Above this strata for about sixty-five feet are soft, greenish, slightly micaceous, then bedded slaty or sandy blocks rather insufficiently exposed in which the only fossil found was a species of Conularia too poorly preserved for identification, but which may be the species described in Ohio as *Conularia newberryi*. This series of strata affords a problem that it is not yet possible to explain. Stratigraphically it may be relatively represented in part by conglomerate II in Ohio which separates the lower and upper Logan, and I am inclined to believe that this may be proven true. Conglomerate II does not extend as far south as the Ohio river. In Ashland county southeast of Mansfield it varies in within a distance of two miles from 3 to 20 feet in thickness. At Wooster, Ohio, it is very nearly one foot thick, while northwest of that place it is 15 feet in thickness. Going directly east from there it is not represented in the valley of the Kilbourn river where the strata afford an otherwise continuous section. It is largely problematic to attempt to bridge over the hiatus from this point to the outcrops in Huron county, but as in the case of the overlying and underlying beds, I think that it will prove true, that the sediments which make up in part at least the remnant of strata which are in the Ohio basin will be shown to have come from the northwest and that these barren strata above mentioned are partially represented by the bed of conglomerate which was deposited at the close of the lower Logan, in Ohio.

Above these unfossiliferous beds there is an abundant fauna, which is the typical Marshall according to Winchell and in all probability is represented by the lower beds of the upper Logan in central and southern Ohio. These species are smaller than in the fossiliferous beds at Grindstone City, indicating somewhat more unfavorable conditions for life quite in harmony with the series of unfossiliferous beds below and above as A. C. Lane says: "The sutures of the Goniatites are more complex than they are below, and there are several species of lamellibranchs, especially aviculoid and solenoid forms and a scarcity of brachiopods." This gives the fauna a facies considerably resembling that over Conglomerate II at Newark, Ohio. This series comes down some eighty-five feet or less below the upper Marshall. The only species identified thus far with the Ohio species from approximately the same horizon are *Ctenodonta hubbardi*, *Grammysia hannibalensis*, *Prothyris meeki*, and *Solen quadrangularis*. In other parts of the state this last species is quite generally distributed. There also occur in the same beds *Nuculana similis*, *Myalina michiganensis*, *Sanguinolites amygda-*

linus, *Goniatites lyoni?* and several other forms which do not afford any data for correlation. In a general way these beds of the lower Marshall conform stratigraphically and palæontologically to the upper Logan, and in the absence of any definite data they might be provisionally regarded as forming a part of that series.

Immediately above this series of strata we have about 300 feet of sandstone which is exposed in the Babbitt quarry near Little Oak Point, at Hat Point, and various places near Tyre, but has proven unfossiliferous. These beds form the Napoleon formation of Winchell, and are succeeded by the beds of the Michigan (Salt Group) Series having a thickness of almost two hundred feet and containing gypsum, which indicates that it was laid down in a body of water largely shut off. It is possible, as Mr. Lane suggests, that this occurred at the time the upper Logan was being deposited in central and southern Ohio, when the strata in the north part of Ohio were above water, until the time of the formation of the Carboniferous millstone grit and thus occupies the gap in the geological column in northern Ohio.

The Grand Rapids or Bayport limestone is extensively quarried in the Grand Rapids and Bayport quarries. It seems to mark without doubt the culmination of the depression during which the sea extended quite far north not long before the deposition of the Coal Measures. In Muskingum county, Ohio, these beds are twenty-five feet thick, while in Licking county a few miles further north they are absent, besides a considerable portion of the upper Logan. However, in the lowest coal measure conglomerate eight miles northeast of Newark, Ohio, a large number of fragments of limestone were broken out which contained a few fossils which can only be referred to the age of the St. Louis or Kaskaskia. These conglomerates are also full of impressions of Lepidodendron and Calamites. The quartz and igneous material are rounded as though transported from a distance. The fragments of limestone, however, are angular and badly decomposed which indicates that they were eroded and carried from no considerable distance, certainly from a source nearer than that which furnished the mass of the rock. We have here then apparently, an explanation of the gap which exists above the highest formation of the lower Carboniferous in northern Ohio, and incidentally of the hiatus which is found in the upper horizons of the different basins in Ohio and Pennsylvania. This correlation is based upon the following species: *Lithostrotion canadense, Spirifer glaber, Athyris subtilita, Allorisma clavata, Allorisma elongata, Schizodus chesterensis, Bellerophon sublævis,* and *Phillipsia longispina.*

The correlations which have here been stated may be modified, but in so far as they relate to Huron county I do not think that any modification will materially alter the relationship. It is reserved for a future time to determine how far the same sequence holds good for the other parts of the state.

Newberry Library, Chicago, Illinois, April 1, 1898.

§ 4. Fossils of the Soule and Bayport limestones.

As we have said the outcrops of the Napoleon sandstones, whether at Hat Point, the Babbitt sandstone quarries, or at any other of the exposures have not yet yielded fossils.

(a). **Soule and Oak Point, Michigan series.***

The Michigan series has also proved sparingly fossiliferous to our researches, but Rominger seems to have been more successful.

Around Oak Point on Sec. 18, T. 18, R. 11, he gives the following list, p. 103.

Productus ventral valve very convex, shallow, sinuated in the median line, and covered by from 40 to 50 sub-equal ribs.

Retzia, like *R. vera*, i. e. *Eumetria marcyi.*

Terebratula like *Cryptonella eudora* (generic reference doubtful).

Spirifer (marionensis)?

Spiriferina (spinosa).

All these specific identifications are very doubtful and the specimens in loose fragments not absolutely in place; crinoids, bryozoa, brachiopods, and bivalves were well represented.

In dredging Caseville Harbor rounded strongly driftworn boulders, of similar lithological character enclosing similar fossils are found, and among them are dark bluish colored fine grained rocks crowded with shells of Myalina, Modiolopsis, Schizodus, with some Rhynchonella, Terebratula, Retzia, etc., intermingled. These may very likely be from sublacustrine outcrops of the Marshall. Winchell found no fossils.

The Productus seems to be near *Productus arcuatus* (Sp. 19009) though our one specimen is badly crushed. One specimen of Spirifer with five striations in the sinus, appears to be *Spirifer forbesi*, the hinge line being quite long. We doubt Rominger's identification of

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*See pp. 12 to 16, 103 to 113.

Sp. marionensis, and probably he only intended to express general resemblance. Quite likely there are other Spirifers present, but all seem to have a striated sinus. The investigations indicate a brachiopodous fauna quite in contrast with that of the Marshall, though apparently most of the specimens come from near the lower part of the series, say the lowest hundred feet.

Geo. H. Girty has found Nautilus, Lituites, Orthoceras, *Spiriferina kentuckyensis* (?), *Productus rushvillensis* (?), Rhynchonella, Derbya and plant remains.

The fauna certainly is not inconsistent with the Augusta (Burlington-Keokuk) group; lithologically it is most allied with the Keokuk. Both Rominger and Winchell assume a closer affiliation of this group with the Bayport rocks than is warranted as it seems to me. Not only is there the difference already described, in lithological character and character of well water, but also a different fauna, so far as I can judge. I have seen fossils from this group in the quarries at Alabaster, Iosco county, and studies in that county will doubtless throw more light upon the subject.

(b). **(Bayport) Maxville limestones.** (200-247 feet above the top of the Napoleon sandstone.) The general equivalent of the outcrops around Bayport, and the islands off the shore, and the outcrops around the Shebeon, and the Charity islands has been remarked by all observers. Under the Lithostrotion beds, are certainly the more compact beds with chert nodules and Syringopora, Allorisma and Productus.

The following table shows the fauna so far as it has been determined. In the first column is given the names of the fossil forms. There is undoubtedly a great deal of synonymy, and probable synonyms so far as the names have been applied to forms in this limestone are grouped together. Identifications which I strongly question are bracketed. In the following columns I have given reference to the author who has mentioned the form in the present connection, and also given the numbers of the Survey specimens, which appear to contain the given form, indicating 19000 by '000, etc. In some cases the numbers and references may not refer to exactly the same but only a similar species, as is more fully explained in the foot notes. I have divided the references into four columns. The first contains all references to the exposures at Bayport, including also the islands of Wild Fowl Bay; the second includes all the references to the Charity islands. The third includes all references to the Shebeon locations, and the last contains references to other places, particularly to Grand Rapids, and to the Maxville limestone outcrops of Ohio.

The palæontological evidence thus accumulated as to the age of these limestones is quite satisfactory. Winchell at first was inclined to think that the limestones in question might include attenuated representatives of the Mississippi limestones from the "geode bed," i. e., upper Augusta up into the Kaskaskia, and in Walling's Atlas he considers that the St. Louis and part of the Keokuk are represented, from the presence of *Lithostrotion canadense* and *Spirifera keokuk.* Rominger does not attempt to assign the horizon closely. Dr. C. H. Gordon visited the Shebeon localities at my request, and from a brief observation, was inclined to place them as Upper Lower Carboniferous, at least as high as the Saint Louis. Whitfield refers the equivalent Maxville limestones of Ohio, to the Saint Louis-Chester groups. Thus there is a prima facie case that the limestones belong in part at least to the St. Louis. But when we come to study the affinities closely, it seems to me that the affinities are more strongly with the Kaskaskia—(Chester) than with the Keokuk. *Allorisma clavata, Zaphrentis spinulosa, Athyris sub-lamellosa, Spirifera glaber,* v. *contractus, Terebratula sub-retziæformis,* and the form which Winchell took for *Spirifer keokuk,* which I think to be near *Spiriferina spinosa,* all point that way, thus agreeing in placing it close to the dividing line between the St. Louis and the Kaskaskia. But the highly characteristic Lithostrotia, *L. canadense* and *L. proliferum* and numerous other forms closely like those in the Saint Louis, viz., *Productus altonensis, Athyris trinucleus, Bellerophon sub-lævis,* together with the fact that it must mark an era of continental depression seem to make it nearly coeval with the top of the Saint Louis, even though the fauna has as strong or stronger affinities with the Kaskaskia. One might be tempted to separate off the Shebeon outcrop with *Zaphrentis,* and *Spiriferina spinosa* and refer them alone to the Kaskaskia, but the Spiriferina is not a typical *S. spinosa,* but is almost certainly the form referred to by Winchell as *Spirifer keokuk* and occurs associated with a form exceedingly like *A. trinucleus* and a Phillipsia. Moreover we are not sure that the Shebeon specimens are above those of Bayport, but even if they are, there is not more than fifty feet or so in the section.

Winchell's general idea seems to be very nearly right, except that the horizon is a little higher than he supposed.

The Lithostrotia are illustrated by Rominger in Vol. III. Pl. LV. The remaining forms must await a closer study of the Kent Scientific Institute, Strong's and the Winchell collection before they can be gone into more thoroughly, and that will be the time to illustrate them.

The fragments of vegetation as yet discovered from the Sebewaing Coal mines do not deserve an elaborate description. Ferns are notably absent, rushes, stems and Stigmaria, are the commoner forms.

References are indicated for the first column thus: R = Vol. III of our reports on p. 120; W. = Winchell's lists given in the 1860 report, pp. 100, 103-110: Our specimens, from 19000-19008 are from the quarries; Sps. 19170—19173 from 725 paces N., 2000 W. in Sec. 36, T. 17 N., R. 9 E.; Sps. 19206 — 19207 from the shore of Wild Fowl Bay; Sps. 19208 — 19219 are from North Island. St. I refers to Stone Island.

For the second column the references are: G. W., list from Charity island by Winchell, 1860 report, pp. 101-110; L. W. list from little Charity, same reference; R. Rominger's list, p. 119; our numbers may be compared with the description of the locality in Chapter V, § 4. For the Shebeon (Cheboyong) W. refers to Winchell's list, 1860 report, pp. 100-113; and possibly some of the forms of Rominger's Bayport list come from the Shebeon.

In the last column M. refers to fossils from the Maxville limestone of Ohio, described by Whitfield, in Vol. VII, of the Ohio reports.

G. R. S. refers to fossils collected by Strong at Grand Rapids, and described in No. 3 of the Proceedings of the Kent Scientific Institute.

No. 8 of these proceedings I have not yet seen.

G. R. W. refers to Winchell's lists from Grand Rapids, 1860 report, pp. 103-110.

Wh. refers to lists of fossils from Grand Rapids, given in a paper by Mr. C. A. Whittemore before the Michigan Academy of Science in December, 1895, (First Report, p. 63), or furnished in MSS by him from the labels of the Kent Scientific Institute Collection. There are a number of other lists given by Rominger at various pages and cited by R. with reference to the page number (111 to 119).

TABLE VI.—FOSSILS OF THE (MAXVILLE) BAYPORT LIMESTONE.

	Locations near Bayport.	Great and Little Charity Islands.	Locations near the Shebeon.	Other locations.
Brachiopoda				
Productus altonenis				G.R. Win.
(4) *Productus pileiformis*, cf. *Productus cora*				Mich.
				Win. M.
Productus (*elegans*) *cestriensis cf. fasciculatus*	.006			? M.
Productus fasciculatus? *Wh.*	N. I			
	'199			
Productus (*Wilberanus*) *nebraskaensis*				?
Productus (delicate) too finely striated for *P. elegans*, too coarse for *P. pileiformis*.		182	246, '247	
P. sanctatus	St. I			Wh. 3 sp.
Productus (unstriated ? *punctatus ?*)	Girty.			G R Win.
Productus ?	R. .006	'176		G.R.Win. R.
		'183		R. 118,113,116
		R.		
Productus flemmingii burlingtonensis		upper beds		Wh.
Streptorhynchus crassum, cf. *Irthis lasellensis* (cf. *Hemipronites crassum*) = *Derbya crassa*			'251	
Orthis umbraculum ? & *O. robusta* with *Phillipsia longispina* cf. *Streptorhynchus umbraculum*		'183		G. R. Win.
Orthis ?	St. I			G. R. Win.
Athyris subquadrata or *trinucleus*	N. 1	'199	'246	G. R. Win.
cf. *T. ambigua*	'192	'192		W. L.
= *Seminula quadrata*		'197		
Athyris sublamellosa		'202		
Athyris ?		'181?		G. R. Win.
Athyris = *Cleiothyris roissyi*				G. R. Win.
Eumetria vera, concentrica		'249		Pt. AuGres.
Spirifera, (*Martinia*) *glaber*, var. *contractus*.		'249		M.
Compare Terebratula rhomboidea, and *roysii*				
Terebratula sacculus or turgida				G. R. Win.
= *Dielasma sacculum*				M.
Terebratula subretziaeformis.				G. R. W.
cf. *Seminula argentea*				
Terebratula	St. I. Win.			

TABLE VI.—CONTINUED.

	Locations near Bayport.	Great and Little Charity Islands.	Locations near the Shebeon.	Other locations.
Atrypa				Pt. AuGres. Wh. G. R. S.
(6) *Spirifer rockymontana*, cf. *opima* and *Keokuk*?) Wh.	'173	'7-'87	'246	M.
Spirifer keokuk v. *Halli*, cf. *Spiriferina spinosa and kentuckyensis*				G. R. Win. Wh.
(1) *Lithostrotion* (*mammillare=canadense*)	R. '003			G. R. W. L.
Lithostrotion (*longiconicum ? = proliferum*)	Girty N. I '217	G. W. '178 '197'180'208	R. 112	G. R. R.
[*Cyathophyllum fungites, vermiculare.*]	R. '001,'110 '208, 212	R. upper '183		G. R.
Cyathophyllum ? More expanded and irregular		Win.		
Caryophyllia duplicata		Win.		
Acervularia ?	Girty ?			
Syringopora ramulosa ?	Girty Win. R. '005	G. W. & L. W. '175 R. up'r. 207		Pt. Au Gres Win. Pt. Au Gres, R. 118.
Zaphrentis cliffordana, Wh.	Girty		'254	M.
Z. spinulosa	R.	R. Pl. L. V.		R. 118, 113, G. R.
Z. spinulifera				Wh.
Archæocidaris				Grand R.
Cyathocrinus maxvillensis, Wh				M.
Crinoid stems, 2 or more species	'006		'246-'250	R. 114. G. R. R.
Pentremites elegans				M.
(2) Bryozoa	R.	N. I '193 '201 '217	'243 '244 '249	G. R. Win. Wh. R. 118. R. 113.
Fenestella membranacea	'170	two spec.		G. R. Win.
Fenestella sp.?				M. R. 111.
Trematopora		R.		R. 113. Gr. R. R. 111
Polypora (cf. *shumardii ?*)	R.	R.		Gr. R. Win.
Polypora varsoriensis ? Wh.				M.
Cladopora ? sp				G. R. Win.
Cladopora ?		G. W.		
Coscinium ?		G. W.		
Monticulipora ? (Rhinopora)				G. R. Win.
Ptilodictya ? (Stictopora)				G. R. Win.
Synocladia rectistyla				
Stylinia astraeformis				
Diphiphyllum constrictum				
(3) Chert nodules	'002 N. I 211 212	'172	179	

tions of *A. andrewsi* Whitfield and *A. elongata* Strong A. seem to be applicable.

Strong's descriptions of *A. elongata* and *A. quadrata* are as follows:

"No. 46. *Allorisma elongata.* (n. sp.) Like the above [*A. sinuata*]," except more elongated posteriorly, wholly without sinus upon the ventral margin or depression upon the valves, and beaks nearer the anterior end. An undistorted specimen of medium size gives the following measurements: Length, 64, height to hinge line, 23.5; height to summit of beaks, 25.4; greatest thickness, 20. Beaks one-ninth the length of the shell from the anterior end (varying in different specimens from one-seventh to one-tenth); twenty-eight concentric ridges —which in this case are pretty persistent—can be counted upon each valve. A specimen one and one-half inches long gave analogous results.

"No. 47. *Allorisma quadrata.* (n. sp.) Like the above, except smaller, relatively broader, with posterior end more quadrate. A specimen of full size, and *undistorted* gives the following measurements: Length, 31; thirty-nine concentric ridges in fasciculi of two, three, or four which often unite upon the posterior end.

"(The author has recently endeavored to refer to the above species described several years since, about seventy specimens, collected this season. He finds none of No. 45, fourteen of No. 46, forty-one of No. 47, and a remainder of heterogeneous material including a few individuals strongly resembling Owen's figure of *A. regularis*; a few not unlike *A. clavata*, and almost every degree of variation between these forms and the three described above. Many resemble Fig. 2, Pl. 22, Vol. V., Pal. Ills. He had formerly believed, that Nos. 46 and 47 were distinct from No. 45, as he had never found them in the same horizon; but recently he has found the two former associated in strata 3 and 4, Taylor's quarry. It is questionable whether we have more than one species of this genus)."

It will be seen that he is inclined to consider them both varieties of *A. sinuata.* As varietal names I think they will stand.

(8.) Strong's description of *Phillipsia longispina* is as follows:

"No. 14. *Phillipsia longispina.* (n. sp.) Outline elongated elliptical sides nearly straight, ends evenly rounded; head, thorax and pygidium nearly equal in breadth.

"Glabella with posterior lobes small, anterior moderately large, evenly convex, without margin; facial suture nearly as in *P. Portlockii* neck segment about as wide as the thoracic, and continued backward in a narrow spine which extends beyond the thorax and is applied so closely to it as not to interfere with the elliptical outline; neck furrow shallow, curving backward strongly and terminating at the lateral furrows of the cheeks. Thorax and pygidium much as in *P. Portlocki* except that the border of the latter is very broad, equaling in breadth the lateral lobes. One specimen from Scribner's quarry yields the following measurements: Length, 44.4; of head 15.3; of thorax, 12.1; breadth of head, 21.2; of thorax, 21.9; of pygidium 20.4."

Notes on the table of fossils from the Bayport and kindred limestones.

(1.) The Lithostrotia are figured by Rominger, Vol. III, Pl. LV, also *Zaphrentis spinulosa.*

(2.) At least four species of bryozoa are well preserved in the Shebeon specimens.

(3.) The chert nodules, which occasionally contain fossils are often pear shaped, with a pit in one end, and apparently there are outlines of sponge spicules in the chert, but Girty found that sections show almost no organic remains.

(4.) The genus Productus is protean. It is impossible for me to eliminate the synonymy. Rominger referred the Producti almost uniformly to *flemmingii,* probably referring to Hall's variety.* Many of them are much like this. But on the other hand there are forms (Sp. 19176), which have marked concentric corrugations of the pattern of *Productus costatus.* Girty finds two species, one *P. punctatus.*

(5.) The Survey specimens, especially the numerous ones in Sp. 19246 are small, and seem nearer *A. trinucleus.* There may be terebratuloids among the forms which we have referred to Athyris.

(6.) The specimens which we have collected from the same locality and can hardly be other than those which Winchell has referred to *Spirifer keokuk,* are distinctly punctate, with line of growth also running back on the ribs. The sinus and fold are variable, either smooth or with one or two ridges. There are about five ridges on either side. The strongly inrolled beak, shape of area, etc., are as Winchell described and like Whitfield's figure of *Sp. rockymontana,*† I cannot but refer it to *Spiriferina spinosa* which is a good deal like *Spiriferina kentuckyensis* and suspect that Winchell's, perhaps also Whitfield's specimens were imperfectly preserved.

(7.) The Allorismas are another protean genus, occurring in great variety of size and form, but most frequently having the sinus from the beak to the ventral margin nearly or quite unobservable. The external ligament is shown by the very frequent occurrence of the shells in pairs, sometimes closed, often spread apart. In sandier layers the shells seem liable to reach a larger size. There are at last two varieties, a small type of which *maxvillensis* Whitfield and *quadrata* Strong seem to be names, and a larger type at times not essentially distinguishable from *subcuneata,* to which the descrip-

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*Geol. Iowa, 1858. Vol. 1. = *P. burlingtonensis.*
†Ohio reports, Vol. VII. Fig. 20, Pl. IX.

GENERAL INDEX.

N. B.—The plants mentioned in the list on pp. 239 to 245, the recent shells listed on pp. 250 to 252, and the fossils of the St. Louis (Bayport) limestone, listed on pp. 298 to 300 are not indexed.

A.

Absorption rates of stone........ ... 211
Acanthaspis........................ 282
Ackerman, J.......... 170
Adams, Anton.................... 162
Adams, I., well of..95, 101, 147, 170, 178, 189, 190
Addison, Mr....................... 200
Adrian.......................... 32
Agnew, Mr........ 184
Ahearn, Ed....................... 190
Ahearn, D........................ 191
Alabaster..................13, 226, 295
Ale, gypsum water for............ 130
Algonquin, lake..51, 75, 76, 79, 81, 82, 87, 89, 204, 228, 248, 283
Allen Creek (river)..39, 45, 77, 86, 93, 288
Allorisma..13, 105, 106, 107, 108, 109, 111, 295, 301
    quadrata..............301, 302
    andrewsi.................. 302
    clavata...........294, 296, 302
    elongata..............294, 302
    regularis... 302
    sinuata................... 302
    subcuneatum.............. 301
Alluvium........................ 9
Alma..................59, 98, 101, 247
Alpena........................29, 160
Altitudes...... ....44, 51
Ambocœlia umbonata............ 286
Amphibole........................ 232
Analyses..133, 135, 138, 146, 175, 177, 178, 209, 214, 216, 218, 225
Anderson, Geo..................... 179
Andrews, E.......35, 78, 82, 83, 84, 286
Ankerite.......................... 231
Ann Arbor........................ 63
Anthracoptera elongata.......... 284
Arenac county.................... 106
Arenaceous shale................ 90
    See also SHALE.
Arkona Beach.................... 65
Arlington House.......... 166
Armbruster, A................... 152
Arnold, N. P...................32, 185
Aroostook county, Maine marl.... 249
Artesian wells................43, 218
    " " failure of.......... 122
Ash, in coal....................... 218
Ashland county, Ohio............ 292
Ashley........................63, 64
Ashquaguindaigue................ 3
    (See synonyms of table I.)
Athyris..................256, 267, 301
    (cf. lamellosa) ohioensis.20, 105, 106, 279
    sublamellosa............. 296
    subtilita.................. 294
    trinucleus.............296, 301
Atrypa reticularis........61, 286, 287
Aublam, A......................... 165
Augusta limestone.........98, 295, 296
    See also MICHIGAN series.

Au Sable River.... 222
Aviculopecten 260
  areolatus 262
Ayres' well..............136, 200, 224

B.

Babbitt, sandstone quarry..16, 90, 96, 207, 293, 294
Bach, C. F....................... 146
Badaxe..10, 43, 45, 47, 49, 70, 87, 123, 128, 133, 137, 138, 173, 174, 175, 203, 207, 209, 227, 244, 248, 249
  flowing well at..43, 86, 90, 172
Baird & Prestage 155
Banker, A. F..................... 198
Bannister 63, 64
Barr, J......................167, 180
Baskin, Geo..................... 158
Battle Creek.........273, 277, 285, 288
Baner, J...12, 14, 100, 103, 111, 113, 114, 145
Bay City...............12, 27, 29, 91
Bayport..10, 12, 14, 19, 28, 48, 75, 87, 91, 97, 98, 107, 108, 121, 124, 127, 134, 136, 138, 145, 161, 163, 178, 230, 234, 240, 242, 243, 244, 245, 249, 295, 296, 297, 298
  limestone..12, 13, 15, 16, 90, 97, 103, 104, 105, 122, 127, 130, 156, 215, 216, 221, 229, 231, 247, 286, 290, 293, 294 295, 298, 301
  quarries near..5, 11, 55, 60, 107, 111, 112, 164, 213, 228, 293, 303
Beach lines....................51, 79
  See also pp. 62, 78 and ELKTON Beach, FOREST Beach, GRASSMERE, LAKE ALGONQUIN.
Beal & Wheeler's Michigan Flora. 239
Bean, H.................. 184
Bear Lake.................10, 56, 203
Beaver dams.................... 202
Beck, Carl 143
Becker, F........ 151
Becker, H....................... 171
Beck's well.... ....91, 147
Bedford shale.....29, 177, 201, 286, 287
Beers, F. W..................... 8
Bellerophon.........106, 107, 284, 303
  barquensis............... 276
  cyrtolites 291
  galericulatus 273, 276, 284, 289
  michiganensis 276
  nautiloides 284
  sublævis................. 294
  urei 273, 274
Benchmark...................36, 37
Benedict, A. C.......111, 213, 214, 215
Berea grit..16, 26, 27, 28, 29, 30, 137, 160, 177, 188, 199, 201, 205, 225, 252, 286
Berea shale..23, 27, 177, 188, 199, 201, 286, 287
Berea brines of................. 135
Bergman, H...................... 166
Berne.....................46, 102, 181
Big Charity Island....... ....97, 105
  See CHARITY Island.
Bingham Township, (T. 15 N., R. 13 E.)..52, 66, 67, 68, 69, 157
  Section 1................. 67
  " 2............66, 67, 157
  " 3................. 68
  " 4..... 68
  " 6................. 69
  " 7................. 69
  " 8..............69, 157
  " 9................. 157
  " 10......... 157
  " 12.......... 67
  " 14.... 66
  " 15....... 66
  " 16................ 158
  " 17................ 158
  " 18................ 158
  " 19.... ......52, 69, 158
  " 20..............66, 158
  " 21................ 158
  " 22................ 66
  " 23..............67, 158
  " 29................ 158
  " 30................ 158
  " 31...........52, 66, 158
  " 32................ 68
  " 34...........63, 64, 65
  " 35................ 65
  " 36................ 66
Bird Creek..................... 128
Bittern....... 225

Black River.................7, 65, 67
Blast furnace.................... 214
Bleicher, J....................... 194
Block stone...................... 207
Bloomfield Township (T. 17 N., R. 14 E.)............43, 52, 133
  Section 5...............92, 93
  " 9.................. 52
  " 20.................. 52
  " 31.................. 52
Blueberry....................204, 241
Blunde, August.................. 167
Bog iron ore..... ....10, 230
Boiler water..................... 130
Bone coal........................ 117
Botanical notes..............234-246
Boulder benches.................. 74
Boulder clay. See TILL......... 11
Boulders..2, 10, 132, 160, 193, 203, 204, 210, 232
Bowsprit......................... 1
Brachiopods..........17, 285, 289, 292
  See names of genera.
Brachythyris..................... 256
Branch county............27, 208, 287
Braun. See BROWN.
Brecciation...................... 107
Brennan, Robt.................. 178
Brick....................208, 210, 212
Brickyard............170, 209, 210, 211
Briuning, A...................... 197
Broken Rocks.............20, 21, 51
Bromine................135, 137, 225
Brookfield Township, (T. 15 N., R. 10 E.)...54, 62, 74, 127, 131, 153, 154, 155
  Section 1.................. 153
  " 2.................. 153
  " 3..............62, 153
  " 5................ 153
  " 6.................. 153
  " 7.................. 154
  " 8.................. 154
  " 10.............102, 154
  " 11.................. 154
  " 13................ 154
  " 14..............53, 154
  " 15.................. 155
  " 21 to 36........... 154
Brown, Jacob................161, 168
  R. A..............93, 174, 177
Bryozoa.. ...20, 104, 106, 261, 279, 301
Buckley, E. R................... 207
Buena Vista Flags.......286, 287, 288
Building stone.................. 108
Bullock, D...7, 160, 161, 162, 166, 170, 173, 178, 179, 189
Burbank, Ohio..............289, 290
Burgess, J. M.................. 156
  S....................... 174
Burley, Wm. F.................. 188
Burlington,................15, 16, 286
Burnt Cabin Point.............7, 40
Buschlein, C..................162, 168
Butler, Capt..................... 215
Buttars, J....................... 200
Byproducts...................... 225

C.

Calamites......................278, 293
Calcite..........................2, 231
Calcium..................104, 133, 142
Calcareous tufa................. 231
Caldwell, H. W.................. 207
Calhoun county................. 280
Camarophoria.................... 269
Camarotœchia (R.) camerifera..17, 21, 23, 92, 267, 268, 271, 278, 290
  hubbardi................ 275
  huronensis............ ... 257
  sageriana................ 291
Campau, Mr..................... 189
Campbell, J. W...114, 145, 146, 151, 191
Campeloma........................ 249
Canada thistle.................. 241
Canadian continent...........16, 99
  rock..................... 61
Caudagalli....................88, 253
Carboniferous..22, 23, 267, 268, 286, 287, 291
  conglomerate....287, 293
Cardinia........................ 285
Cardiopsis crenistriata.......... 274
  megambonata............. 274
Carpenter, Mr................191, 200
Carrington...........28, 200, 204, 224
  salt block.............. 241
Carver, Mrs..................... 154
Casey, James.................... 192
Caseville..3, 10, 19, 25, 26, 28, 29, 30, 40, 46, 50, 77, 87, 95, 98, 101, 102, 103, 120, 124, 127, 170, 181, 203, 211, 224, 225, 234, 243

Caseville harbor.................. 294
township,(T.17 N., R. 10 E.) 126, 129, 178, 211, 225, 233
Section 1.............101, 178
" 2.............101, 179
" 3................. 120
" 10................. 179
" 11................. 179
" 12................. 179
" 13..95, 101, 103, 126, 129, 179, 211, 225
" 14................. 179
" 15................. 179
" 16.............103, 233
" 21................. 179
" 22................. 180
" 23.............103, 180
" 24................. 180
" 25................. 180
" 26..........61, 103, 180
" 27................. 180
" 28................. 180
" 29................. 180
" 30................. 180
" 31................. 181
" 32.............103, 181
" 33................. 181
" 34................. 181
" 35...........61, 91, 181
" 36................. 181
township, (T. 18 N., R.10 E.) 188
Casing..................123, 124, 129
Cass City..................63, 100, 221
River.........53, 66, 70, 128
Valley........... 68
Cassinke, J....................... 173
Cathartic water...............161, 167
Catskill series..............15, 19, 189
Cement....1, 98, 168, 186, 208, 217, 227
Centronella flora................. 20
julia..........24, 246, 269
See ROMINGERINA julia.
Cephalopods..................289, 290
Ceratites........................ 281
Chalcopyrite.................... 229
Challis, W....................... 165
Chalcedony.................2, 104, 230
Chalybeate waters.............. 135
Chamberlin, T. C.........121, 126, 127
Champine, Alex................. 189
Champlain epoch..............5, 62
Chandler Township, (T. 17 N. R. 11 E.)...14, 130, 131, 182, 184, 185, 216, 226, 240, 241, 242, 243, 244
Section 2.................. 182
" 3...............96, 182
" 4.................. 182
" 5..............101, 182
" 6..............101, 182
" 7..............130, 182
" 8..............101, 182
" 9..............101, 182
" 10.................. 183
" 11..........54, 183, 240
" 14.................. 183
" 16..............101, 183
" 17..............101, 183
" 18..........108, 183, 216
" 19.................. 183
" 20.................. 183
" 21.................. 183
" 23..............183, 226
" 24.....100, 101, 183, 216
" 25..........100, 101, 184
" 26...............59, 184
" 28.................. 184
" 30.................. 184
" 31.................. 184
" 32.................. 184
" 33.................. 184
" 34.................. 185
" 35.................. 185
" 36..........14, 101, 185
Channels, glacial drainage........ 69
underground water..... 113
Chappell, W. T...113, 114, 123, 145, 220
Chapin.......................... 64
Charity Island..2, 7, 57, 104, 106, 107, 203, 230, 242, 243, 244, 295, 297, 298
Cheboyong creek................ 3
See SHEBEON.
Chemung shales........19, 24, 284, 287
Chert.................61, 230, 295, 301
Chiastolite schist................ 60
Chicago lake.................... 84
Chips of wood in boring.......153, 154
Chiton.......................... 277
Chittenden, Col. H. M............ 37
Chlorine..132, 133, 134, 138, 139, 140, 141, 142

Chlorine. See also ANALYSIS.
Chlorite........ 233
Chonetes........26, 88, 253, 267
pulchella........ 88
illinoisensis........ 276
scitulus...88, 252, 253, 286, 288
Church, Bros.........182, 191, 199
J......... 186
Wm......... 182
Churchill well, Alpena........ 29
Christmas run, Ohio........ 289
Cincinnati anticline........ 288
Citric acid........ 139
Cladodus concinnus........109, 282
See also FISH.
Clark, A. N., analysis by........ 209
Henry........ 186
J. M........ 272
Clark's station........ 45
Clay iron stone........ 19
Clays........89, 99, 203, 208, 212
Cleveland shale........29, 160
Stone Co.......199, 206, 207
Clifford........ 46
Climate........31, 99
Clymenia........ 282
Coal..1, 99, 115, 145, 146, 148, 192, 193, 199, 217, 218, 219, 221, 233, 279
Coal measures...113, 145, 148, 213, 287, 293
Coast survey, U. S. See U. S.
Cochliodus........ 282
See also FISH.
Codey, M.........100, 183
Colander, Thos......... 196
Coldwater shales.24, 26, 86, 93, 120, 176, 177, 188, 196, 197, 199, 208, 213, 252, 262, 263, 265, 286, 287, 288
Cole's saw mill........ 154
Cole, W. H......... 198
Colfax Township, (T.16 N.,R.12 E.) 52, 69, 70, 71, 73, 95, 96, 100, 102, 122, 127, 128, 173, 174, 209, 210, 248
Section 1........ 173
" 6......62, 102, 127, 173
" 7........100, 173
" 9........ 173
" 13........173, 209, 210
" 18........ 173
Colfax Township,
Section 20........ 173
" 23........ 173
" 24.......95, 96, 173, 248
" 26........ 174
" 27........ 174
" 29........ 174
" 30........ 174
" 31........71, 73
" 32........ 174
" 33........ 174
" 34........70, 174
" 35........ 174
Collison's well.14, 100, 102, 161, 222, 223, 229
Colts, Mark........ 185
Conley, Henry........188, 190, 224
Conglomerate..1, 17, 18, 22, 23, 26, 176, 181, 190, 199, 200, 201, 266, 267, 278, 286, 289, 292
jasper........11, 61
lighthouse........ 23
peanut........19, 21
Conrad, Mr......... 281
Conularia........26, 282
gracilis........88, 253, 288
newberryi........ 292
Cookingham, E. R......... 8
Cooper, J. R......... 205
Cooper, W. F...23, 26, 247, 252, 253, 255, 261, 262, 277, 279, 282, 295
Copper........60, 228, 229
Copper furnaces, use of sand in.204, 205
Coral........ 104
Coreyell, J...91, 144, 175, 176, 181, 189
Corless, Mr......... 188
Corniferous cherts........ 61
See HELDERBERG.
Corry sandstone........ 286
Cowper, M. well of........93, 177
Crafts, Mr......... 168
Cranberry bog........57, 203
Crawford........ 28
Crawford, F.........188, 189, 224, 225
Creel........ 46
Creevy siding........ 45
Crenipecten........261, 262, 270
caroli........261, 279
winchelli........270, 291
Crinoids........20, 267, 278, 279
Crosman, Chas.........35, 37, 44
Cross-bedding........ 104

Crushing strength................ 215
Cryptonella....................246, 271
eudora................291, 294
Ctenacanthus.................... 278
Ctenodonta....................... 276
(nucula) sectoralis........ 276
hubbardi.................. 292
Cucullella cultrata................ 261
Cumber spillway.................. 248
Curran, Mr....................... 188
Curry Arch....................... 159
Cussewago shales................ 286
Cuyahoga...18, 23, 24, 27, 86, 252, 253, 263, 265, 286, 287, 288, 289, 291
River.............287, 288, 289
series..................... 252
valley..................... 15
Cyathocrinus..................... 261
Cyathophyllidæ.............104, 106
Cypricardella.................... 267
barquensis................ 260
Cypricardia....................... 260
bellistriata............... 286
Cypris.........................109, 279
Cythere........................... 109
crassimarginata.......... 277
Cyrtiæ............................ 269
Cystina........................... 269
Cyrtoceras tesselatum........... 280

D.

Dana, J. D...................228, 233
Davidson, Mr...................... 259
Davis, Prof. C. A...5, 50, 105, 131, 138, 140, 141, 142, 173, 203, 227, 230, 234
Geo...................... 162
T........................ 154
Decher, J......................... 168
Deeg, Christ..................14, 153
DeKoninck, Prof................. 280
Dentalium barquense............ 276
Derbya crassa........259, 267, 291, 295
Detroit............................ 207
Devonian...........22, 23, 30, 253, 267
black shales.......23, 268, 289
Dewing, H......................... 160
Diabetes, effect of mineral water on 128
Diamond Creek................77, 88
Dibb, M........................... 185
Dictyophyton..................... 287
Dip..20, 86, 87, 95, 97, 108, 110, 112, 113, 115
Dixon, Mr......................... 201
Dolomite....104, 106, 107, 108, 137, 231
Dominis, H........................ 181
Donaldson, S...................... 158
Dorrance grate................... 220
Dow House........................ 138
Draining swamps................. 122
Dreher, A.......................... 154
Drowned Point..................... 82
Drummond, J...................... 183
Duffield, S. P..................... 136
Dufty, Wm.........14, 19, 101, 189, 190
Dugway quarry, Ohio.........262, 289
Dunes..9, 40, 51, 56, 143, 210, 236, 237, 241
Dunster block..................... 207
Durand, J. D...................... 154
Dwight & Heywood................ 170
Dwight Township, (T. 18 N., R. 13 E.)..17, 20, 52, 55, 73, 74, 92, 93, 99, 125, 128. 133, 192, 193, 194, 195, 240
Section 1............75, 92, 192
" 2...............92, 192
" 3.....17. 55, 74, 93, 193
" 5.................. 193
" 6.................. 193
" 8.............128, 193
" 9.................. 193
" 11.................. 193
" 12.........125, 133, 193
" 13.....17, 55, 73, 93, 194
" 14.................. 194
" 15.................. 194
" 16.................. 194
" 17.................. 194
" 18.................. 194
" 20...............92, 194
" 21...............52, 194
" 22...............17, 194
" 23............17. 20, 195
" 24.................. 195
" 26...............17, 195
" 27.................. 195
" 28.................. 195
" 30.................. 195
" 31...............52, 195
" 32.................. 195
" 33.................. 195

Dwight Township,
  Section 34.................. 195
  " 35..............17, 195
  " 36..............52, 195

E.

Eagle Bay....................24, 199
Eakins, Mr....................... 190
Earth crust movements.......... 77
Ebert, L.......................... 143
Edmondia Cf. binumbonata ...262, 263
  burlingtonensis........... 290
Edwards, J. P. 4
Eichler, Mr...................... 184
Eimer, H.....................164, 165
Einwochter, Henry.............. 169
Elevations..................44, 51, 77
Elkton.......10, 49, 74, 75, 89, 102, 123
Elkton Beach 79
  brickyard 210
Ellenbaum, S..................... 169
Elm Creek........................ 1
Elm Island........................ 82
Emergence, rate of, from Lake... 83
Encrinal..................29, 160, 177
Endersby, Aaron................. 156
Engelhard, B..................... 150
Engert, Geo. A................... 177
Engler, L......................... 162
Epidote.......................... 232
Erb, O...............178, 184, 186, 192
Erie shale.......................29, 177
Erosion................34, 41, 80, 82
  of shore.................. 42
Escarpments............55, 69, 93, 94
Esker..........................53, 72
Estman, Mrs...................... 161
Eumetria marcyi................. 294
  polypleura........256, 260, 291
Euomphalus...................... 303
  carinatus................ 257

F.

Fairchild, H. L.................. 74
Fairgrove........................ 184
Fair Haven Township, (T. 16 N., R. 9 E.)...3, 14, 100, 102, 111, 126, 127, 130, 160, 213, 222, 224, 226, 248, 250
Fair Haven Township,
  Section 1 160
  " 10................ 160
  " 11.............160, 222
  " 12.............111, 160
  " 13................3, 160
  " 14..14, 111, 161, 213, 224
  " 15.............100, 161
  " 16.............102, 112
  " 21.............161, 222
  " 22...........3, 126, 161
  " 23................ 161
  " 24................ 161
  " 25.............102, 162
  " 26.........102, 162, 248
  " 27.............162, 248
  " 28................ 162
  " 33................ 162
  " 34.............100, 248
  " 35................ 162
  " 36................ 163
  township, (T. 17 N., R. 9 E.)
  Section 36..........91, 111, 178
Fall, Prof. D.................160, 167
Falle, Chas....................... 143
Farmer's map....................7, 202
Farwell, Jerome................. 192
Faults................92, 112, 113, 129
Feldspar......................232, 233
Fenestella...........105, 109, 279, 284
Ferns............................ 297
Fertilizers....................203, 226
Figures referred to:
  Figure 1................. 1
  2...........15, 16, 103
  3................ 74
  4...........78, 79, 84
  5...........25, 87, 88
  6..96, 97, 101, 102, 106, 110, 112, 116, 118, 120
  7................ 105
  8..109, 110, 111, 213, 214, 215
  9..104, 111, 112, 121, 122, 138
  10.....113, 114, 126, 220
  11...............21, 113
  12.........121, 124, 125
Filion, H...45, 95, 128, 186, 187, 193, 244
Finkbeiner, C................147, 169

Finkbeiner, J.................... 162
Finkel, J........................ 155
Fireclay.......................... 115
Fires, effect on soil of............ 203
Fire stone......................... 109
Fish............................ 22
  fragments.................. 279
  Point....................... 116
  spines...................... 279
  teeth...............279, 282, 283
Fisher, Mr....................166, 183
  O. S....................... 220
Fissure......................113, 125
Fistulipora....................... 277
Fixed carbon...................... 218
Flach and Conley..........188, 189 224
Flagstaff......................... 1
Flat Rock Point..3, 7, 16, 17, 20, 92, 278, 279, 280
Fleming, Geo. N..............113, 274
Fliege, Mr........................ 170
Flint. See CHERT................ 108
Flora.......203, 234, 235, 237, 238, 245
Flowing wells...107, 112, 121, 123, 125, 126, 127, 128, 134, 145, 146, 152, 154, 156, 160, 161, 162, 163, 164, 165, 170, 171, 172, 173, 175, 178, 179, 182, 190, 192, 193, 200
  effect of weather and wind on, see WEATHER.
Fold............................ 97
Forbes, Mr........................ 196
Forest Beach..63, 64, 70, 71, 75, 79, 159, 177, 208, 209, 212, 227, 248
Forestville.................27, 28, 208
Fort Wayne......................... 63
Fossil plants...............12, 21, 246
Fossils..12 to 26, 92 to 94, 96, 104 to 112, 245 to 301
Foster and Whitney's report..... 35
Franklin, B........................ 167
Fremont, M........................ 194
French River...................... 84
Fruits............................ 238
Frye's Physical Geography....... 54
Fucoides cauda galli............. 268
Fuller, M. L...................35, 38
  S. M........................ 181

G.

Gagetown...........46, 52, 63, 64, 209
Gaine, Mr......................... 189
Galena...........161, 221, 222, 223, 228
Ganoid scales................282, 283
Gardner, J...................101, 179
Gannett.....................44, 48, 232
Garrigues, Dr. S. S.....4, 141, 160, 199
Genesee shale...................... 188
Geode bed.......................... 296
Geological column................. 9
  Survey of Michigan...170, 177, 188, 199, 200, 247, 262, 263, 264, 265, 266, 270, 283, 286
  See also SPECIMENS.
  Survey of Ohio...261, 264, 265, 266, 270
  Survey of the United States. See GILBERT, GIRTY.
Gericke, Mr........................ 182
Gerstenschlager, J............... 177
Gettel, Henry..................... 143
  Mrs. J..................... 143
Gettz, Mr.......................... 198
Gilbert, G. K..5, 6, 36, 37, 62, 77, 83, 84
Ginter, Mr........................ 210
Girty, Geo. H...6, 253, 255, 278, 295, 301, 303
Glacial epoch..................60, 168
Glaciers.......................... 11
Glass sand..................99, 104, 168
Goniatites..21, 22, 26, 27, 88, 89, 253, 261, 278, 279, 281, 282, 285, 292
  allei....................... 283
  cyclolobus.................. 281
  henslowi.................... 281
  hyas........................ 281
  lyoni.........279, 281, 291, 293
  marshallensis..20, 231, 253, 281, 283
  mixolobus................... 281
  oweni....................... 253
  propinquus.................. 278
  serpentinus................. 281
  shumardianus................ 278
Goodman Logging R. R........48, 49
Goodwill, Sam..................... 172
Gordon, Dr. C. H...5, 6, 56, 65, 93, 133, 142, 253, 296
Gore Township, (T. 18 N., R. 15 E.) 198
  Section 17.................. 2
  " 18........................ 198
  " 30........................ 198
  " 32........................ 198

Gore Township,
Section 33.............. 198
Gotts, P. O................. 190
Gould, Mr...............182, 184
Grammysia hannibalensis......... 292
Grand Rapids..12, 13, 14, 170, 217, 296, 297
group....145, 148, 153, 222, 223
limestone.............. 292
quarries............... 293
Granite..............11, 61
Grant, A................. 165
D................. 165
township, (T.15 N.,R.11 E.) 52, 73, 100, 131, 132, 155, 156, 240
Section 1..............71, 155
" 6................ 155
" 7..............53, 156
" 8................ 156
" 11..............71, 156
" 13..............71, 156
" 14................ 71
" 15................ 52
" 16................ 156
" 17................ 156
" 18..............63, 156
" 19................ 71
" 20................ 63
" 21................ 63
" 22..............63, 156
" 28................ 71
" 29................ 71
" 31..............63, 71
" 32................ 63
" 34................ 63
" 35................ 156
Granville, Ohio..............264, 288
Grassmere....48, 49, 130, 171, 172, 173
Beaches............64, 74, 79
Grate for coal.............. 220
Gratiot county.............. 129
Gravels...........61, 67, 68, 69, 74, 212
Graves, A............... 165
J...............143, 146
Gray, Asa..............238, 239
Greenbush, N. Y., Benchmark.... 44
Greenleaf, Jeremiah (Universal Atlas).............. 7
Greenleaf Township, (T. 14 N., R. 12 E.) Sanilac county.
Section 32.............. 248
Gregory, M. C............... 179
Gremel, F. J............... 143
Grice, Jos............... 81
Grill, John.............. 171
Grindstone City..18, 22, 24, 28. 41, 86, 87, 90, 93, 173, 196, 199, 239, 240, 244, 245, 269, 290, 291, 292
Grindstone quarries.16, 17, 21, 176, 177, 199, 206, 271, 274, 275, 277, 283
Grindstones....1, 90, 170, 192, 205, 207
Gritstone............17, 205, 253, 277
Gritzner, Ed............... 191
Green, Joseph.............. 146
Gull Island..............105, 238, 242
Gypsum...14, 98, 99, 101, 102, 103, 104, 113, 130, 133, 134, 138, 141, 153, 161, 164, 167, 170, 173, 178, 180, 182, 184, 185, 190, 226, 233

H.

Haeberlein's brewery....114, 129, 145
Haffner's well............100, 112, 162
Hagen, J............... 158
Hall's, J. well.............. 200
Hall, James, cited...246, 254, 258, 259, 263, 264, 266, 270, 277, 280, 281, 284, 301
Hamilton facies.............. 286
group..28, 61, 137, 160, 177, 216, 259, 287
Hanselman.............. 159
Harbor Beach (Sand Beach)..26, 27, 28, 29, 30, 32, 35, 40, 43, 45, 46, 58, 78, 82, 87, 88, 93, 133, 135, 136, 137, 138, 160, 196, 209, 225, 234, 240, 287, 288
Harder, E............... 165
F. G............... 165
J. B............... 165
Hardpan.............. 10
Hardwood Point..3, 17, 20, 40, 92, 95, 190, 230, 253, 279, 280, 281, 383, 285
Hare, J. H............... 156
Harrington, W. J............... 201
Harrison, Richard.........157, 158
Hartmann, W........160, 167, 182, 183
Harvey, Mrs............... 183
Haskell, Miss..............190, 204

Haskell, N. A...................28, 224
Hat Point...16, 19, 57, 90, 92, 203, 240, 241, 293, 294
Hayes, P. O............32, 33, 179, 211
Hazard R. I. 173
Head of wells................121, 126
See also FLOWING wells.
Heaton, W. I..................... 184
Heckert, C....................... 169
Heist, Mr.... 210
Heistermann, Mr......... ....107, 222
(See STONY ISLAND.)
Held, Mr. 249
Helderberg brines................ 135
limestone...13, 30, 61, 177
Helena 45
Helodus 109
Hematite 230
Henderson, Dr. Jas.............. 248
Henning, Chas................155, 221
Henry, A. J...................... 37
Wm............................. 162
Herrick, C. L....18, 23, 26, 246, 247, 258, 260, 261, 263, 264, 265, 266, 268, 270, 271, 274, 281, 282, 283, 284, 285, 286, 288
Hetherington & Rasher, analysts. 136
Hicks, L. E...................... 288
Hiduler, B....................... 81
Hill, Mr......................... 183
Hillsdale..............59, 281, 283, 288
Hinton, Wm...................... 169
Hoeldke, Martin..............94, 159
Hoffman, Mr...................... 171
Hofmeister, C. J....7, 143, 146, 147, 152, 153, 162, 164, 165, 166, 168
Hoist, Jacob 168
Holland, Mich................280, 289
Holmes, J. A....... 178
Hood, museum..................... 247
Hornblende................11, 61, 232
Hotel Hannah..................... 114
Houghton, Douglas....2, 3, 35, 41, 246
Howell, frost at 32
Hubbard, Bela..................2, 196
Hudson Bay....................... 249
Hume Township, (T.18 N., R.12 E.) 3, 19, 120, 190, 192, 227, 240, 242, 244, 283
Section 2...............95, 283
" 7...........3, 19, 95
" 10..............95, 190

Hume Township,
Section 11................. 190
" 12..........52, 120, 190
" 13...............52, 191
" 14................. 191
" 15................. 191
" 19................. 191
" 20...... ...95. 191, 227
" 23................. 191
" 25................. 72
" 26................. 192
" 27................. 192
" 28................. 192
" 31...............52, 192
" 32................. 192
" 34................. 52
" 35................. 192
" 36................. 192
Huron City...10, 24, 196, 240, 241, 242, 253, 268, 269, 270
county..103, 117, 121, 131, 227, 234, 235, 237, 246, 247, 286
Grindstone Co............ 206
group.....18, 255, 257, 258, 266
lake 79, 242
lobes.... ....66, 68, 69
Salt Co.................. 224
shales.........29, 177, 188, 266
Huron Township, (T. 19 N., R. 14 E.)...17, 24, 74, 75, 133, 196, 243, 244, 290
Section 2................. 196
" 3................3, 74
" 4..............92, 196
" 5... 196
" 6................. 196
" 7................. 196
" 8...........52, 92, 196
" 9..............92, 197
" 10................. 197
" 11................. 197
" 12...........76, 81, 197
" 13................. 197
" 14................. 197
" 15................. 197
" 16................. 197
" 17..............92, 290
" 19................. 197
" 21..............92, 198
" 24........... 198
" 28...........17, 93, 198
" 29................. 198

- **Huron Township,**
  - Section 30 .... 24, 198
  - " 31 .... 52, 198
  - " 32 .... 52, 92
  - " 33 198
  - " 34 198
- **Hutchinson, J.** 173
- **Hydrogen sulphid** 133, 135, 159, 192

I.

- **Ice age** 60
- **Illinois** 16
- **Improper casing** 124
- **Indiana** 12, 15, 16, 32
- **Indians** 8, 76, 222
- **Ingall, Mr.** 178
- **Inoceramus** 285
- **Iosco county** 295
- **Iowa geology** 15, 16, 277, 301
- **Irion, H.** 152
- **Iron** 138, 142, 145
  - See also ANALYSES.
  - ore (bog) 10, 91
  - stone clay 19
- **Isle au Traverse** 7

J.

- **Jackson, Wm.** 199
- **Jahnke, A.** 143
  - **Carl** 154
- **Jenks, Geo. J.** 80, 82, 224
- **Johnson** Station 45
  - **Prof. J. B.** 214, 215
- **Johnson, Peer & Wallace** 206
- **Jones, C.** 189
- **Jonesville** 59

K.

- **Kain, Jacob** 169
  - **Louis** 168
- **Kalamazoo** valley 290
- **Kames** 68, 71
- **Kaolin** 233
- **Kappen, W.** 168
- **Kaskaskia** formation 12, 13, 293, 296
- **Keane, Chas.** 178
- **Kedzie, F. S.** 137, 175
  - **R. C.** 136, 178
- **Kelly, W.** 187, 194
- **Kennedy, Mr.** 191
- **Kent Scientific Institute** 247, 297
- **Kentucky** 286
- **Keokuk formation** 16, 286, 295, 296
- **Keyes, C. R.** 15
- **Kilbourn River,** Ohio 292
- **Kilkenny, P. O.** 47, 169
- **Kilmanagh, P. O.** 50, 153, 169
- **Kimball** Island 20
  - **J. K.** 36, 44
- **Kinch, Mr.** 201
- **Kinde** 45, 187
- **Kinderhook** 19, 23, 268, 291
- **Kindig, Geo.** 169
- **King, J.** 156
  - **Miles** 156
  - **Prof.** 269
  - **Thomas** 198
  - **W.** 189
- **Kleaber, Geo.** 161
- **Kleinschmidt** 163
- **Klemmer, J.** 100, 173
- **Knaski, J.** 195
- **Kobeld** 143, 144
- **Konkel, Mr.** 220
- **Kramer, Geo.** 168
  - **Mrs.** 199
- **Kreutziger, B.** 127, 173
- **Kuehn, W.** 147
- **Knla, Mr. V.** 201
- **Kundinger, Geo.** 153

L.

- **Lackey, Mr.** 186
- **Lake Algonquin.** See ALGONQUIN.
  - Chicago 84
  - currents 34
  - Huron 35, 42, 127, 208, 243
- **Lake level** 35, 44, 84
  - **Nipissing.** See NIPISSING.
- **Lakes** 56
- **Lake Survey,** U. S. See U. S. LAKE SURVEY.
- **Lake Warren** and other Lakes. See name of lake.
- **Lake Township,** (T. 18 N., R. 11 E.) 16, 19, 52, 91, 95, 96, 99, 100, 189, 207, 294
  - Section 15 .... 16, 207
  - " 18 .... 189, 294
  - " 23 189

Lake Township,
  Section 24................ 189
  " 25................ 189
  " 26................ 189
  " 30...91, 95, 96, 99, 100
  " 32..............19, 190
  " 34................ 190
  " 35..............19, 190
  " 36..............52, 190
Lambert, Mr...................222, 223
Lamellibranchs..20, 21, 22, 24, 277, 284, 288, 289, 292
  See also names of genera.
Land plants....... 22 and chapter IX
Lane, A. C...7, 50, 131, 142, 145, 247, 248, 252, 287, 289, 292, 293
  F...................173, 287, 293
  Mrs. A. C.................. 249
Langley, Prof..................... 214
Lansing......................32, 175
Lapham, Dr. J. A.............. . 44
Latham, Mr...................... 200
Laurentian...................... 87
Lawrence, Mr.................... 179
Lawton, C. D................... 4
Layer, Jacob.................... 177
Layhen, Gottleib................ 169
Lea, Mr.......................... 249
Lead..........................155, 161
Learned, J. R...28, 75, 92, 190, 199, 200
Leiopteria torreyi.....20, 92, 253, 284
  halli.................... 291
Leipprandt, C. F....33, 95, 101, 103, 129, 179, 211, 225
Lepidodendon........117, 276, 277, 293
Leptaena rhomboidalis........... 286
Level of lakes..............35, 44, 84
Leverett, F......................61, 62
Libby.........................101, 179
Liberty, Jackson county, Mich.... 277
Licking county, Ohio..264, 266, 270, 287, 288, 289, 293
Lighthouse. See POINT AUX BARQUES lighthouse.
Liken, Henry, Jr................ 147
  J. C...114, 116, 143, 144, 145, 146, 149, 166
Lime............................ 108
Limestone...1, 2, 30, 55, 100, 104, 107, 108, 109, 110, 111, 145, 208, 210, 212, 213, 231
Limestone. See also MAXVILLE, BAYPORT, SOULE, and HELDERBERG.
Limonite......................... 230
Limnæa........................... 249
Lincoln, S........................ 178
Lincoln Township, (T. 17 N., R. 13 E.)...52, 72, 73, 122
  Section 5................. 187
  " 6................. 187
  " 7................. 52
  " 18...............52, 187
  " 19................. 187
  " 20............72, 95 187
  " 21................. 72
  " 22................. 187
  " 29................. 72
  " 30...............52, 187
  " 31............52, 72, 187
  " 32...............72, 187
  " 33.......... 72
  " 34................ 72
  " 35................ 72
Lindeberger, A................... 166
Link, C........................... 169
Linkville......................... 169
Lithostrotion..4, 13, 105, 106, 107, 108, 109, 110, 166, 178, 294, 295, 297, 301
Little Charity Island..........105, 106
Little Oak Point...............96, 293
Lituites........................... 295
Loch, Thomas.................... 158
Lock.............................. 93
Lockman, Mr..................... 192
Lodi, Ohio....................... 288
Logan group (Ohio)...14, 15, 16, 263, 264, 265, 270, 286, 288, 291, 292, 293
Lonsberry, J................19, 96, 182
Lower Forest Beach....... 64
  See FOREST BEACH.
Lower Grand Rapids...........98, 153
Lower Marshall formation....120, 125, 127, 137, 138, 166, 173, 174, 176, 181, 189, 197, 199, 230, 231, 232, 252, 253, 264, 269, 270, 279, 282, 286, 291, 293
Lower Mississippian............. 267
Lucht, John...................... 168
Lundy, Mr....................199, 200

- **Lutson, B.** 103, 181
- **Lutz Farm** 149
- **Lynch, J. E.** 170
- **Lyriopecten** 270

M.

- **Macadam** 212, 214, 215
- **Macfarlane's** Geographical Railway Guide 4
- **Macrodon** 264
  - hamiltonae 286
- **McAllister, Robt.** 191
- **McArdle, Frank** 183
- **McArthur, Mr.** 154
- **McBrine, Mr.** 196
- **McCauley, F. D.** 164
- **McCoubrie, James** 130, 182
- **McCoy, Mr.** 274
- **McCrea, D.** 177
- **McDonald, Mr.** 197
- **McGargle, Mr.** 193
- **McKay, Mrs.** 189
- **McKenzie, W. A.** 155
- **McLaren, Mr** 189, 192
- **McLean and Reed** 192
- **McMillan, Chas.** 159
- **McPhail, D.** 156
- **McPherson, Mr.** 184
- **Magnesia** 139, 140
- **Magnetic variation** 2
- **Maier, H.** 165
- **Manganese** 231
- **Mansfield,** Ohio 292
- **Malphus, Mr.** 183
- **Marcasite** 219, 223, 229, 233
- **Marl**...10, 70, 71, 191, 226, 227, 249, 250
  - shells of......9, 10, 53, 203, 247
- **Marotski Ch.** 143
- **Marshall,** formation...3, 14, 16, 17, 18, 22, 23, 25, 26, 30, 55, 86, 89, 90, 91, 94, 96, 99, 107, 111, 120, 122, 148, 153, 205, 232, 247, 252, 253, 260, 265, 268, 269, 271, 273, 275, 277, 280, 281, 282, 283, 284, 285, 290, 292, 293
  - sandstones..56, 69, 127, 128, 158, 173, 230, 273, 277, 280
  - shales....232, 247
- **Martini and Campbell** 145, 146
- **Martinia** 256, 267
- **Mason, L. P.,** wells of....91, 178
- **Mattawa** valley 76, 77
- **Matz, Fritz** 153
- **Mauch Chunk** shale 189
- **Maumee** Lake 63
- **Maxville limestone** (of Bayport) 12, 15, 98, 103, 107, 120, 145, 247, 286, 290, 295, 296, 298
  - See BAYPORT.
  - (of Ohio)....12, 13, 297
- **Maxwell, A. and T.** 183
- **Maywood, C. G.** 117
- **Meade Township,** (T.17 N., R.12 E.) 52, 73, 123, 185, 216, 240
  - Section 2 185
  - " 3....74, 185
  - " 4.... 185
  - " 5....96, 185
  - " 6....52, 55, 96, 185
  - " 7.... 185
  - " 8.... 185
  - " 9.... 123
  - " 12.... 185
  - " 14.... 185
  - " 15....55, 96, 186
  - " 16.... 96
  - " 17.... 186
  - " 18....96, 100
  - " 19......96, 100, 186; 216
  - " 20.... 186
  - " 21.... 186
  - " 22.... 186
  - " 27.... 186
  - " 29.... 186
  - " 32.... 186
  - " 33.... 186
  - " 36.... 52
- **Meagher, Ed.** 200
- **Medina county,** Ohio 263
- **Meek, F. B.** 263
- **Melanterite** 233
- **Melonites** 278, 281
- **Meredith, Mr.** 172
- **Merista** (houghtoni)..254, 257, 260, 267, 279
- **Merjelen See** 67
- **Mica** 232
- **Michigan** Cement Co. 216
  - lake 77
  - series..13, 14, 15, 16, 96, 98, 99, 102, 103, 112, 129, 136, 138, 145, 149, 164, 167, 168, 170, 186, 216, 221, 223, 286, 290, 293, 294

Michigan Standard Coal Co....114, 213, 219, 220
Microdon reservatus..........260, 270
Minden City..................45, 46
Midland...............59, 98, 101, 129
Miller....................12, 114, 168
Milwaukee, water level at.......36, 37
stone 98, 216, 217
Mines.........................113, 218
Minerals......................... 228
Mineral waters...1, 128, 129, 130, 132, 134, 141, 159, 179, 210
Mintline, D..................101, 188
Mississippi limestones........... 296
valley.................... 103
Missouri..............16, 212, 223, 266
geological survey......... 142
Modiolopsis 294
Moeller, H.................. 163, 181
Moisture......................... 218
Mold 203
Monroe county 126
Moose River...................... 249
Moot's Run.................26, 287, 288
Moraine................67, 68, 70, 74
Morrison, Mr.................157, 196
Moscow, Michigan...277, 280, 281, 283
Mosey, Mr......................... 186
Mosher, Mr......178, 183, 184, 186, 193
Mosner, Mr...............129, 146, 222
Mott, Mr.......................... 175
Mud Creek....................48, 50
Mud Lake 53, 71, 78, 227, 240
Mueller, Adam.................. 165
F...................... 164
Muller, Henry 145
Munsteroceras oweni.........278, 279
Murdens, S. J...................... 200
Murdock, J. J...................... 180
Muskingum county, Ohio......... 293
Myalina 270, 294
michiganensis 292
pterinæformis.........273, 284

N.

Napoleon series (upper Marshall), 3, 13, 14, 15, 17, 18, 20, 21, 30, 90, 91, 96, 98, 99, 100, 101, 102, 103, 110, 112, 116, 118, 120, 122, 123, 125, 126, 127, 128, 129, 130, 136, 141, 143, 145, 146, 147, 149, 151, 153, 163, 166, 167, 176, 181, 183, 184, 186, 207, 221, 252, 277, 285, 286, 293, 294, 295
Nash, Wm......................... 199
Nautilus.................277, 295, 303
Neely, A.......................... 170
Nettle Run....................... 49
Neuropteris 277
Newark, Ohio....262, 263, 288, 289, 293
Newberry.....................29, 184
See Ohio correlations.
Newman, J......................... 180
New River salt well..24, 26, 27, 28, 74, 86, 87, 93, 201, 204, 224
Newly, Andrew 171
See Neely.
New York 20, 286
Niagara Falls, erosion of......... 83
Nims, W........................... 32
Nipissing, Lake......76, 77, 79, 83, 84
Noble, W.......................... 192
North Charity Island..240, 241, 242, 243, 244
See also Charity and Big Charity Island.
North Island...3, 97, 106, 107, 108, 110, 213, 232, 297
Nucula 270, 276, 279, 281
hubbardi......24, 277, 279, 281
iowensis..............270, 289
stella..................... 277
Nuculana......................... 20
bellistriata...277, 279, 284, 291
diversa 279
similis............279, 289, 292
ventricosa 277
Nuculites fallax.............282, 284
Nugent, Richard 158

O.

Oak Grove............114, 123, 129 218
Oak Point....2, 7, 13, 14, 57, 90, 96, 99, 204, 294
Oborski, John.................. 159
Ochre 230
Ohio correlations...14, 15, 29, 99, 103, 107, 266, 268, 283, 284, 285, 286, 287, 289, 290, 291, 292, 293, 297, 301
shale 29

Oil 199
Old Bayport 136, 180, 181
Oliver Township, (T.16 N., R.11 E.,), 15, 52, 55, 71, 74, 91, 102, 126, 131, 170, 171, 172, 173, 210
Section 1 52
" 2 170
" 3 .... 170, 210
" 4 170
" 5 170
" 6 170
" 7 170
" 8 170
" 9 .... 126, 171
" 10 171
" 11 171
" 12 171
" 13 171
" 15 172
" 16 .... 55, 91, 172
" 17 15
" 18 172
" 21 172
" 22 172
" 23 102
" 27 172
" 28 172
" 29 172
" 30 173
" 31 173
" 33 .... 102, 173
" 35 52
" 36 173
Olmstead, Mr. 185
Oriskany 30
Orodus 278
Orthis crenistria 259, 260
iowensis 259
michelini 259, 267, 279
vanuxemi 258, 259, 267, 286
Orthoceras 267, 268, 278, 280
barquianum 266
cinctum 280
clinocameratum 280
goldfussaneum 280
indianense 20, 280, 284
multicinctum 284
rushense 268
Orton, Dr. Edward 263, 286
See also OHIO correlations.
Ostracoda 267
Ottawa county 280, 289
Owen 154, 302
Owenda e. .. 46, 89, 102, 131, 133, 154, 224
Oxbows 54, 57

P.

Paint rock 91
Palæoneilo attenuata 288, 289
concentrica 288, 289
marshallensis 291
sulcatina 281, 284
Palms 45
Panama, N. Y. 284
Paris Township, (T.15 N., R.14 E.) 43
52, 63, 65, 66, 67, 94, 133, 158, 159
Section 1 158
" 3 52
" 6 67
" 7 158
" 8 158
" 11 158
" 12 158
" 13 159
" 16 .... 94, 159
" 18 .... 52, 67
" 19 52
" 20 .... 67, 95, 133, 159
" 23 159
" 24 159
" 26 .... 94, 159
" 28 67
" 29 159
" 31 65
" 32 .... 66, 159
" 33 .... 66, 67
" 34 159
" 36 159
Parisville 52, 94
Parma sandstone 12, 13, 104
Parmelee, H. P. 59
Paving brick 212, 213
Peanut conglomerate 19, 20, 291
Pearson, J. 200
Pebbles 208, 210
Peer, A. G. 3, 206
Pennsylvania 286, 287, 293
Pere Marquette R. R. Co. 6, 45
Pewamo outlet 64, 74, 79
Phacops bufo 61
Phæthonides spinosus 253, 288
Phelps, W. L. 196
Phillips, Prof. 259, 271, 274, 281

Phillipsia........ 296
  longispina........294, 302
  portlockii........302, 303
  pygidia........ 105
Pigeon..10, 19, 46, 49, 57, 91, 165, 166, 171, 212
  River..3, 7, 46, 47, 53, 74, 75, 223, 243
  Furnace Co......189, 224
Pine Island........ 76
  stub........ 81
Pinnebog........133, 192, 210, 222, 223
  River...39, 47, 49, 54, 57, 75, 96, 100, 186, 191, 209, 239, 240, 242, 243, 244
Pisidium........ 247
  contortum........248, 249, 252
  elongata........ 273
  milium........ 249
  ventricosum........ 250
Plain district........ 54
Plants........234, 235, 236, 238, 239
Plates of this part referred to:
  1........9, 27, 29, 30, 87
  2........ 2
  3........ 21
  4........35, 40, 41
  5........2, 25, 35, 37
  6........5, 62, 63, 65
  7..44, 86, 91, 94, 97, 98, 101, 116, 118, 120, 127, 213, 216, 223, 226
  8..13, 31, 42, 59, 63, 66, 96, 118, 120, 202, 203, 204, 216
  9........11, 60
  10..21, 247, 252, 253, 254, 255, 256, 258, 260, 262, 268, 271
  11..20, 247, 253, 254, 260, 261, 262, 263, 264, 265, 266, 268, 270, 276, 282, 283
Plaster........1, 181, 203, 225, 226
  See GYPSUM.
Plasticity........209, 213
Pleistocene........9, 145, 148, 153, 176
Pleurotomaria........25, 270, 278
  huronensis........ 257
  strigellatta........ 291
Polypora........105, 109
Porosity........90, 119
Point au Chapeau. See HAT POINT 3
Point aux Barques..1, 2, 7, 16, 17, 21, 36, 37, 40, 41, 55, 56, 87,
Point aux Barques, 90, 92, 94, 141, 201, 241, 244, 270, 272, 273, 274, 275, 276, 277, 278, 283, 288, 289, 291
Point aux Barques grindstone quarries. See GRINDSTONE 3
Point aux Barques lighthouse..3, 87, 88, 201, 208, 221, 229, 233, 247, 252 to 270, 279, 285, 288, 289, 290, 291
Point aux Barques sandstone..17, 18, 93, 176, 253, 278
Point aux Chenes. See OAK POINT........2, 7
Point au Pain Sucre (Hat Point) 3, 278, 280
Point Charities. See SAND POINT 40
Point of Pines........ 21
Pontiac, Oxford & Northern R. R. 46
Popple P. O.........69, 97
Pores in rock........ 207
Port Austin..4, 10, 17, 20, 24, 26, 27, 28, 34, 36, 37, 40, 41, 44, 45, 58, 77, 87, 93, 94, 95, 124, 125, 135, 136, 194, 200, 203, 204, 205, 209, 222, 234, 238, 239, 240, 241, 242, 243, 244, 245, 249, 253, 279, 282, 283, 284, 290, 291
Port Austin sandstone...176, 194, 253, 279, 285
Port Austin Township, (T. 19 N., R. 13 E.)..3, 13, 17, 20, 21, 50, 52, 74, 92, 93, 94, 199, 200, 201, 206, 240, 283
  Section 21........ 93
  " 22........17, 92
  " 23......17, 21, 199, 206
  " 24........ 206
  " 25........199, 206
  " 26.......17, 21, 92, 199
  " 27........52, 93, 199
  " 28........ 200
  " 29........ 200
  " 30........50, 200, 206
  " 31........74, 200, 283
  " 32........ 200
  " 33........ 200
  " 34........ 200
  " 35..3, 17, 20, 92, 94, 201
  " 36........ 201
  T. 19 N., R. 12 E......199, 279

Port Austin Township,
Section 24 ... 279
" 25 ... 199
" 36 ... 199
Portage shales ... 19, 23, 27
Port Crescent. . 20, 28, 40, 58, 87, 95, 124, 128, 134, 135, 138, 190, 192, 204, 205, 239, 240, 241, 242, 243, 244, 245, 253, 283, 284
Port Hope ... 253
Salt Co. ... 224
wells . . . 24, 26, 27, 28, 88, 188
Port Huron & Northwestern R. R. 45, 64
Portland Cement. See CEMENT. 208, 217, 227
Portsmouth, Ohio ... 263
Posidonomya ... 278
Praseham, Paul ... 172
Precipitation ... 32, 33
Preglacial Valley ... 59, 110
Prescott, Prof. A. B. ... 136, 171, 178
Prevailing winds ... 34
Productus. . 13, 25, 106, 109, 111, 253, 260, 267, 268, 269, 276, 279, 282, 287, 294, 295, 301
arcuatus ... 294
blairi ... 253
burlingtonensis ... 301
concentricus ... 276
costatus ... 301
flemmingii ... 105, 301
lævicosta ... 88, 253
marshallensis ... 295
newberryi annosus. . 253, 288
punctatus ... 301
rushvillensis ... 295
shumardianus ... 253, 288
Proetus ... 254, 261
auriculatus ... 266
missouriensis. . 23, 253, 254, 261, 266, 267, 291
Prothyris meeki ... 253, 265, 292
Psammodus ... 282
Pterinea ... 284
cardinata ... 272
Pyrite. . 1, 11, 12, 19, 61, 117, 144, 152, 153, 160, 161, 162, 163, 166, 168, 178, 189, 199, 213, 220, 221, 229
Pyroxene ... 232

Q.

Qualitative tests of water. . 138 to 201
Quality of mineral water ... 141
Quarry ... 164
See also BAYPORT, BABBITT, GRINDSTONE.
Quartz ... 229, 230, 232
Quartzites ... 61
Quinn, John ... 183

R.

Raccoon creek, Ohio ... 288
shales ... 286, 288, 289
Radloff, T. ... 165
Rapson, A. W ... 183, 191, 193
T. . . 173, 174, 176, 187, 191, 194, 195, 196, 198, 199
Rapson's Siding ... 45
Rather, H. ... 134, 160
Chas. ... 167
Ratio of absorption ... 214
Raw material ... 202
Red rock ... 91, 145, 146, 147, 171
Beed, Mr ... 192
Regenscheit, M. ... 168
Rehbein, August ... 163
Reinhold, Ernst ... 210
Reithel, F. J. ... 167, 168
Mr. ... 166
Reither, J. ... 165
Retzia ... 267, 294
polypleura ... 256
Rhynchonella. . 17, 25, 254, 255, 267, 268, 271, 278, 279, 282, 285, 294, 295
barquensis ... 274
camerifera. . . . 21, 271, 274, 275
circulars ... 275
hubbardi ... 275
huronensis. . 254, 255, 256, 257, 258
increbescens ... 269
radialis ... 271
serpentina ... 256
subcircularis ... 271
vera ... 256
Rhynchonelloids ... 253, 270, 279
Rhynchospira ... 260
Richardson, James ... 158

- **Riddle, Wm.** 182
- **Ries, H.** 6, 7, 89, 208, 210
- **Riever & Studer** 147
- **Rievert, E.** 147
- **Ritter, Max** 186
- **River sand** 190
- **Road metal** 212
- **Robertson, Geo. S.** 206
- **Robinson, Geo.** 17, 73, 194
- **Rock Falls**. 23, 26, 88, 252, 253, 287, 288
    - ridges 106, 110
    - salt 30, 225
    - surface 87
- **Roger's Point** 7
- **Rolph, D.** 171
- **Rominger, Dr. Carl**...4, 7, 11, 12, 13, 14, 16, 17, 18, 21, 22, 24, 26, 27, 88, 91, 92, 96, 98, 104, 105, 109, 160, 189, 199, 215, 217, 226, 246, 253, 255, 260, 268, 271, 278, 281, 282, 291, 294, 295, 296, 297, 301
- **Romingerina (Centronella) julia**.. 17, 21, 24, 25, 86, 92, 246, 253, 254, 269, 270, 271, 285, 290, 291
    - zone..25, 26, 276
- **Rose, F. E.** 162
- **Ross, J.** 154
- **Rubicon Township,** (T. 17 N., R. 15 E.) 52, 188
    - Section 4 188
    - " 15 188
    - " 27 188
    - " 33 52
    - " 35 188
    - " 36 188
- **Ruppert & Sanders** 147
- **Rushes** 99, 297
- **Rush Lake**......10, 57 78, 96, 207, 243
- **Russell, John**..6, 113, 116, 143, 146, 147, 148, 150, 153, 163, 168
- **Ruth**.........45, 69, 82, 86, 94, 203, 227
- **Ryan, J.** 200, 210

S.

- **Saginaw**............12, 59, 66, 98, 215
    - Bay...2, 7, 45, 46, 106, 114, 116, 128, 129, 148, 280
    - Coal Co...114, 116, 127, 147, 148, 150, 218, 219, 220
        - mines 126
- **Saginaw**
    - Lake 63, 65, 72
    - lobe of ice sheet........68, 69
    - River 91
    - Tuscola & Huron R. R..45, 50, 71, 74, 75
    - Valley.........18, 123, 237, 250
- **St. Clair**.......................29, 30
    - outlet 76
    - River 30, 78
- **St. Louis** Formation.13, 15, 16, 293, 296
    - See also BAYPORT and MAXVILLE.
- **Salina** (or South Saginaw)........ 98
- **Salt.** See also CHLORINE and SPECIFIC GRAVITY. 1, 103, 128, 129, 134, 170, 188, 224
    - group. See MICHIGAN SERIES 293
    - rock 30
    - rocks 16, 28, 224
        - See also names of towns listed on page 28.
- **Sand** 204, 243, 244
- **Sand Beach**...26, 27, 28, 29, 30, 40, 43, 45, 58, 93, 135, 196, 240
    - See HARBOR BEACH.
        - township, (T. 16 N., R. 15 E.) 93, 177
    - Section 5 177
    - " 12 177
    - " 18 177
    - " 19 ....93, 177
    - " 25 177
        - township (T. 16 N., R. 16 E.)...........177, 178
    - Section 30 178
- **Sand dunes**..204, 235, 239, 240, 241, 242, 243, 244
- **Sand Point**.........10, 40, 57, 106, 107
- **Sandstone**..2, 11, 12, 13, 14, 15, 17, 20, 25, 26, 30, 87, 90, 104, 108, 109, 110, 115, 129, 133, 134, 177, 205, 252, 255, 263, 270
    - See also MARSHALL, NAPOLEON, POINT AUX BARQUES, PARMA, SCHIZODUS, WAVERLY, WOODVILLE, SYLVANIA.
- **Sandy beds** 268
- **Sanguinolites**................253, 267
    - aeolus 263
    - amygdalinus 285

Sanguinolites,
borealis 275
concentricus 285
flavius 288, 289
marshallensis 275
michiganensis..........282, 283
naiadiformis.. 291
strigatus............ 276
unioniformis 275, 288
Sanilac county.............65, 94, 208
Sawyer, Wm..................... 191
Schack, Geo...................... 161
Schad, Philip 186
Scharizer, L...................... 191
Schizodus..20, 23, 253, 260, 263, 267, 278, 279, 294
æqualis 264
æquimarginalis 265
binumbonata 265
macrodon............... 264
subovata 263
triangularis 260, 264, 266, 269, 291
Schlaach, Wm.................... 198
Schmucker, John................. 188
Schneider, C. F.................. 32
Schoolcraft, H. R...............1, 2
Schubach, D.................103, 180
Schubel, Chas.................... 196
Schuch, Geo...................... 222
Mrs..................... 162
Schuchert, Carl 222
Schultz, Henry................... 166
Sciotoville, Ohio 287
Scolithus......................... 269
Scribner's quarry................ 302
Scythestones.................206, 207
Sears, W. B...................... 45
Sebewaing. .3, 4, 12, 40, 44, 46, 48, 49, 50, 52, 56, 59, 60, 86, 97, 100, 102, 103, 104, 111, 112, 113, 115, 123, 127, 129, 140, 147, 148, 150, 208, 212, 221, 245
Sebewaing brickyard........ 210, 211
coal 218, 219
Co....113, 114, 117, 146, 218, 219, 220
Creek........ .....57, 77
marble works... 207
measures........ 11
Mining Co..144, 148
Sebewaing Creek
mines..7, 92, 112, 129, 223, 229, 233, 297
township, (T. 15 N., R. 9 E.)...12, 13, 14, 50, 52, 62, 76, 86, 91, 99, 100, 115, 116, 126, 143, 145, 146, 147, 151, 152, 153, 220
Section 1................ 143
" 2................ 143
" 3................ 143
" 4...... 143
" 5................ 143
" 7...12, 13, 14, 115, 143, 220
" 8...12, 13, 14, 100, 126, 145, 220
" 9................ 146
" 10......... .....91, 146
" 11..............62, 146
" 12................ 147
" 14..............52, 147
" 15..............126, 147
" 16..............91, 147
" 17..12, 50, 62, 116, 147, 220
" 18..12, 50, 62, 76, 116, 126, 148, 220
" 20................ 151
" 21..........99, 116, 151
" 22................ 151
" 23................ 151
" 26................ 151
" 27................ 151
" 28................ 151
" 29................ 151
" 30..............62, 152
" 31................ 152
" 32 152
" 33................ 152
" 34................ 152
" 35...........14, 86, 153
Severn, John......... 181
Shales..89, 91, 100, 207, 208, 209, 212, 213, 252, 266
See also COLDWATER SHALES.
Shawangunk 2, 7
Shebeon..3, 47, 49, 53, 111, 160, 213, 222, 223, 295, 296, 297, 298, 301
Shell marls.........9, 73, 176, 247, 248

Shells....247, 250, 251
Sheridan....43, 69, 122
  township, (T. 15 N., R. 12 E.)....53, 69, 72, 156, 157
  Section 1.... 156
  " 3.... 157
  " 6....69, 157
  " 8.... 157
  " 9....69, 157
  " 10....69, 157
  " 11.... 69
  " 12.... 69
  " 13.... 157
  " 18.... 53
  " 21.... 69
  " 24....69, 157
  " 25.... 157
  " 30....53, 69, 72
  " 35.... 157
  " 36.... 157
Sherman Township, (T. 15 N., R. 15 E.)
  Section 7....52, 69, 159
  " 12....93, 159
  " 30.... 159
  " 31....94, 159
  " 32.... 159
  " 35.... 52
  (T. 15 N., R. 16 E., see WHITE ROCK TOWNSHIP, which has been annexed.)
Sherzer, W. H.....62, 126
Ship Point.... 2
  See POINT AUX BARQUES.
Shodwell, Mr..... 156
Shoreline.... 39
Shufeldt, Mr..... 154
Shumard, Mr.....261, 266
Shungwoigue. See STONE ISLAND 3
Sigel Township,(T. 16 N., R. 14 E.) 43, 52, 67, 71. 86
  Section 17.... 69
  " 18....52, 69
  " 19.... 52
  " 21.... 69
  " 25.... 93
Silicious concretions.... 13
Silurian.... 30
Silver Creek.... 49
Sinclair, Mr..... 190
Sinda, John.... 158
Sink hole....101, 190
Skene's well....20, 21
  See also PORT AUSTIN.
Slickensides.... 113
Smalley, B..... 207
Small fruits.... 238
Smeder, P..... 193
Smith, Gershom Wilson.... 184
  H. O..... 193
  John P.....36, 180
  Lawrence.... 178
  Mr..... 168
  W.....153, 162, 163, 201
Snell, T.....161, 166
Soapstone....174, 207
Soda.... 140
Soils....132, 202, 203
Solen....20, 22, 253, 267, 279, 285
  priscus.... 261
  quadrangularis....279, 282, 292
Solenopsis....261, 267
Sommerville, Mr..... 193
Soule..13, 14, 89, 100, 145, 186, 190, 216, 231, 232, 294
South Devon.... 254
South Saginaw.... 98
Sovereign, E.....14, 91, 95, 96, 99, 100, 178, 189
Sowerby, Mr..... 280
Spalding, Mr..... 194
Specific gravity....135, 140, 142
Specimens of Mich. Geol. Sur. collections referred to:
  19000.... 300
  1.... 299
  2....230, 231, 299, 300
  3.... 299
  4.... 226
  6.... 90
  7....299, 300
  8.... 300
  9....100, 216
  19010....231, 281
  1....229, 231, 278, 282
  2.... 272
  3.... 278
  4.... 278
  5....233, 278
  6....233, 278
  7.... 90
  8.... 231
  19020.... 230
  3.... 282

Specimens of Mich. Geol. Sur. collections referred to:
19028........ 282
19032........ 277
3........ 278
6........268, 269
7........230, 269, 270
8........ 270
19040........ 270
1........ 270
2........ 270
3........ 270
4........254, 255
5........254, 259, 260, 261
6........90, 254
7........ 254
8........254, 255
9........ 254
19050........254, 261
1........257, 258
2........ 254
3........ 254
4........ 254
5........ 254
6........258, 261
7........258, 260
8........258, 257
9........ 258
19060........254, 259
1........254, 261
2........254, 260, 261
3........ 254
4........254, 261
5........254, 261
6........ 254
7........254, 260
8........233, 254, 261
9........231, 254, 261
19070........254, 257, 261
1........ 254
2........ 254
3 ....254, 256, 257, 260, 261
4........ 254
5........254, 257, 267
6........254, 267
7........254, 267
8........ 254, 267
9........ 254
19080........ 254
1........ 254
2........254, 260, 267
3 254

Specimens of Mich. Geol. Sur. collections referred to:
19084........ 254
5........ 254
6........ 254
7........90, 254
8........ 254
9........231, 254, 278
19090........231, 278
1........ 231
2........90, 231, 272
3........ 231
4........231, 254. 272
19101........ 96
2........90, 96
3........100, 216
4........100, 216
5........100, 216, 231
6........ 270
7........ 231
8........ 90
9........100, 282
19110........ 299
2........ 283
3........ 281
4........ 284
7........ 283
8........278, 284
19125........230, 284
6........ 283
7........283, 284
8........283, 284
19132........ 280
3........ 282
6........278, 282
7........230, 281
9........ 282
19140........281, 283, 284
1........283, 284
2........ 283
3........280, 283, 284
5........230, 283, 284
6........ 282
7........ 253
8........ 253
9........ 253
19150........ 253
2........ 90
8........ 231
9........226, 233
19161........90, 96, 207
8........ 211

Specimens of Mich. Geol. Sur. collections referred to:
19170..........108, 297
1..........108, 297, 300
2..........108, 297, 299
3..........108, 297, 299
4..........230, 231
5.......... 299
7.......... 300
8..........105, 299
9..........105, 230, 300
19180..........105, 299, 300
1.......... 105
2.......... 105
3..........105, 299
4..........105, 300
5..........105, 300
6..........105, 300
7.......... 105
8.......... 106
9..........106, 300
19190.......... 106
1..........106, 230
3.......... 299
5.......... 300
6.......... 300
7.......... 209
19201.......... 299
5.......... 299
6..........297, 299
7..........109, 297, 299
8..........107, 297, 299
9..........107, 297
19210..........107, 297
1..........107, 297, 299
2..........107, 297, 299
3..........107, 297, 299
4..........107, 297, 300
5..........107, 297
6..........107, 297
7..........297, 299
8..........297, 300
9.......... 297
19222..........100, 216
3..........100, 216
5.......... 211
6.......... 211
7.......... 211
19233.......... 233
19246..........299, 300
7.......... 300
19252.......... 300
6.......... 264

Specimens of Mich. Geol. Sur. collections referred to:
19257.......... 264
8.......... 270
19260..........260, 264
1.......... 266
2.......... 265
3.......... 255
4.......... 262
5.......... 255
6.......... 255
7.......... 256
8.......... 256
19271.......... 258
2.......... 258
3.......... 268
4.......... 268
7.......... 263
8.......... 262
9.......... 283
19280..........261, 266
1..........261, 266
2.......... 283
3.......... 282
4.......... 282
Spencer, J. W., cited...39, 41, 62, 64, 247
Sphalerite..........221, 229
Sphenotus..........260, 267, 270
æolus.......... 263
Spherosiderite.......... 231
Spirifer..25, 253, 254, 256, 260, 267, 278, 284, 294, 295
centronatus.......... 261
centronota..........253, 291
deltoideus..........254, 261, 289
forbesi.......... 294
glaber..........294, 296
huronensis..........254, 255, 291
insolita.......... 256
keokuk..........112, 296, 301
marionensis..........262, 294, 295
medialis.......... 254
pharovicina.......... 255
rockymontana.......... 301
stratiformis.......... 262
subattenuatus.......... 254
Spiriferina..112, 260, 267, 294, 295, 296
kentuckyensis (cristata) 295, 301
spinosa..........294, 296, 301
Springs..........54, 131, 162
Stahl, S........... 163

Starbeck, Wm ... 191
Staurolite schist ... 11, 232
Stearns, R. E. C ... 252
Steinman, W ... 179, 212
Sterki, Dr. Victor ... 7, 247, 249
Stewart, Chas ... 179
Stictopora ... 267
Stigmaria ... 117, 297
Sting, Jacob ... 153
John ... 151
Stoll, Mr ... 178
"Stone" cited ... 111, 207, 213
Stoney Island ... 3, 107, 158, 297, 298
Strebiopteria media ... 253
Streptorhynchus ... 260, 267
robusta ... 259
String, J ... 166
Strong, E., cited ... 246, 297, 301, 302, 303
Strophomena rugosa ... 259
Stueck, E ... 168
Sugar Point ... 7
River ... 7
Sulphates ... 102, 103, 113, 140, 142, 201
Sulphur ... 218, 219
Susalla ... 93, 94
Swamp ... 202, 203
Sylvania sandstone ... 30, 205
Synclinal fold ... 92, 93
Syringopora ... 295
ramulosa ... 105, 106, 109
Syringothyris ... 255, 256, 260, 267, 268, 285
carteri ... 290, 291
herricki ... 256
pharovicina ... 253, 255, 260

T.

Tarr, R. S ... 62
Tarry, J. G ... 161, 221, 226
Tawas Bay ... 226
Taylor, F. B ... 5, 61, 62, 63, 64, 65, 67, 69, 75, 76, 83, 84
Taylor's quarry ... 302
Temperatures ... 33, 34
of well waters ... 142, 145, 146, 149, 152, 154, 161, 162, 165, 166, 170, 172, 173
Terraces ... 53, 62, 155
Terebratula ... 260, 267, 294, 296
subretziaeformis ... 296
Tests of waters ... 138, 141
Thompson, Frank ... 169
James ... 186
Joseph ... 195
Moses ... 201
Thumb of Michigan ... 1, 65, 71, 72
Thunder Bay limestone ... 2
Till ... 11, 53
See MORAINES.
Tilt, Mr ... 187
Time, estimates of ... 78, 82, 84
Timothy ... 10, 203, 244
Tischendorf, Mr ... 198
Titz, T ... 167
Topography ... 39, 42
Traverse group ... 28, 29, 137, 160, 177
Tremain & Clark ... 224
Trenton ... 30
Trilobites ... 107
See PHILLIPSIA and PROETUS.
Tucker, J. H ... 80, 81
Tuscola county ... 100, 127, 221, 231
Tyre ... 45, 96, 293
channel ... 65, 66, 79

U.

Underpinning, rock used for ... 207
Underwood, Wm ... 201
Undrained hollows ... 177
Ubly ... 11, 45, 133, 157
Unionville ... 59
Union House ... 114
Upham, W ... 62, 70, 84
Upper Forest Beach ... 69
See FOREST BEACH.
Grand Rapids series ... 153
See MAXVILLE LIMESTONE.
Helderberg ... 61
See HELDERBERG.
Marshall ... 97, 98, 120, 128, 137, 145, 153, 166, 176, 181, 183, 184, 252, 285, 286, 292
See also NAPOLEON.
Mississippian ... 223
Urinometer, to test specific gravities ... 140
U. S. Alkali Co ... 136
Engineers ... 7, 35, 44, 76, 80
Geological Survey ... 5, 7, 35, 39, 42, 44, 121
See also G. K. GILBERT.

U. S. Alkali Co.,
Lake Survey...8, 41, 43, 44, 81, 82, 105, 112
Land Survey........7, 8, 81, 105

V.

Valvata tricarinata.............. 249
Van Wormer, Mrs. Mary......... 81
Variation of flow of wells..122, 123, 145, 146, 155, 156, 163, 184, 198, 200
See also WEATHER.
Vaughan, Prof. V. C............. 137
Vitrification...................... 209
Verona Mills............11, 65, 69, 288
Verona Township, (T. 16 N., R. 13 E.)..43, 52, 67, 73, 80, 128, 137, 174
Section 2................ 72
" 6............... 174
" 7...........52, 71, 174
" 8................ 71
" 9................ 71
" 10................ 52
" 11...........71, 72, 174
" 12................ 70
" 14................ 70
" 18..............52, 175
" 19. 70, 89, 90, 95, 128, 174, 175
" 20.............70, 176
" 21...........52, 70, 176
" 22...........22, 68, 176
" 23..............52, 61
" 24................ 68
" 25................ 176
" 27................ 68
" 28................ 68
" 29..............68, 177
" 31.......... 51, 68, 177
" 34................ 177
" 35...........52, 67, 177
Volatile carbon 218
Voltz, A.......................... 147
C.......................91, 146
D. H....................... 147

W.

Wad 231
Wade, Evan.................197, 199
Wadsworth, M. E................. 5
school house.......45, 167
Wagner, W....................... 167
Wallace, A. H................... 228
L. R............... 199, 206
W. H................111, 224
Walker, T........................ 191
Bryant............7, 247, 250
Walling's atlas........4, 7, 8, 105, 296
Walsh, J......................... 192
Mrs. P.................. 156
Ward, Mr......................... 191
Warren county, Ohio............. 287
Warren, Lake 72, 73, 74, 79
Warren, H........................ 209
Water..43, 89, 107, 112, 129, 131, 132, 133, 134, 138
channels.................. 125
supply.................... 177
Watertown arsenal, test at....... 215
Waverly group..2, 18, 23, 262, 263, 264, 265, 266, 270, 285, 286, 288, 289, 290
sandstone...........2, 262, 286
Weather, effect on of wells..147, 149, 151, 156, 161, 167, 171, 172, 173, 179, 198, 200
Webber, Hon. W. L....5, 6, 50, 60, 70, 160, 176, 178, 181, 228
Mrs. W. L...........117, 303
Weeks, J. D...................... 160
Weight of stone.................. 90
Weinlander, Wm.................. 168
Weiser, Carl.................161, 162
Weiss, F.......................... 198
Welch, T......................... 154
Wells, Cyrus G................... 171
Welsh, T......................... 189
Wettzel, Fred.................... 173
Wheatfield, Mich................ 277
Wheeler, Prof.................... 241
Whelihan, J...................... 192
Wm................... 192
Whetstones....................... 22
Whitechurch, Mr................. 194
White Rock..7, 26, 27, 28, 29, 41, 56, 75, 76, 81, 82, 86, 87, 89, 136, 227, 287
township, (T. 15 N., R. 16 E.)..52, 81, 89, 159, 208
Annexed to Sherman tp.

White Rock Township,
Section 6................ 159
" 7................ 52
" 20................ 81
" 29................ 159
" 32..............89, 208
Whitfield, Mr.....13, 107, 296, 297, 301
Whitmore, C. W................ 297
Whitney, (Foster & Whitney's report) 35
Whittlesey, Chas. 35
Lake..63, 65, 67, 68, 69, 72, 79
Wilcox, H....................... 175
Wild Fowl Bay.3, 5, 7, 105, 107, 290, 295, 297
Williams, Eakins & Soule.....190, 224
Williams, H. J................... 6
H. S.................. 23
Mr................... 200
Willow Creek..7, 10, 17, 18, 21, 24, 37, 39, 53, 55, 70, 72, 77, 79, 87, 90, 128, 196, 206, 269, 270, 290, 291
Wilson, John................... 158
W....................159, 195
Winchell, Alex...3, 4, 6, 7, 11, 12, 13, 14, 16, 17, 18, 19, 20, 22, 25, 26, 31, 32, 87, 88, 91, 98, 99, 104, 106, 107, 108, 109, 199, 206, 228, 246, 247, 252, 254, 255, 259, 260, 261, 262, 263, 264, 266, 267, 268, 269, 271, 274, 276, 278, 279, 280, 281, 282, 283, 284, 285, 290, 291, 292, 294, 295, 296, 297, 301
Wind..........................34, 41
effect on wells. See WEATHER, VARIATION, etc.
Winsor................46, 59, 102, 169
Windsor Township,
(T. 16 N., R. 10 E.)
Section 3................ 103
" 4..........50, 61, 103
" 5...13, 50, 75, 103, 104, 108, 110, 213
" 9................ 110
" 11................ 91
" 15................ 110
" 18................ 91
" 21................ 50
" 22................ 110
" 23................ 74
" 25................ 59
" 28................ 102
" 29................ 102
" 30................ 102
" 31................ 102
" 32................ 102
" 33................ 102
" 36................ 75
Winter, C...................143, 151
Wisconsin.................15, 61, 82
Geological Survey...207, 216
Wisner benchmarks............ 36
Wisner, L........................ 153
Witwer cheese factory........... 159
Wood in drift.................... 154
Woodchucks..................... 51
Woodville sandstone............. 11
Woodward, Mr................... 70
Woodworth, T. B.............101, 182
Wooster, John................172, 194
Ohio...263, 288, 289, 290, 292
Worthen cited 281
Wressel, Geo..................... 196
Wright, A. L.................... 174
C. E................5, 26, 189
Dr. W. C..76, 160, 187, 200, 222
Well 120
Wurm, John.................... 158

DESCRIPTION OF PLATE X.

Figs. 1, 2. *Chonetes scitulus* Hall. View of pedicle valve and of brachial and pedicle valve in conjunction. Upper Coldwater horizon. Point aux Barques lighthouse, Huron county, Michigan.

Fig. 3. *Spirifer huronensis* A. Winchell. Pedicle valve of an average individual. Upper Coldwater horizon. Point aux Barques lighthouse.

Fig. 4. *Spirifer deltoideus* Herrick. Brachial valve. The striæ are not preserved towards the hinge line. Upper Coldwater horizon. Point aux Barques lighthouse.

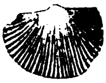
Figs. 5, 6. *Syringothyris pharovicina* A. Winchell. Brachial and pedicle view of two individuals.

Fig. 7. Specimen showing: c, cardinal area; d. delthyrium: e, dental plate; p, tubular portion of tranverse plate; t, internal cast of tube. Upper Coldwater. Point aux Barques lighthouse.

Figs. 8, 9, 10. *Camarotœchia huronensis var. precipua* A. Winchell. Pedicle, profile and ventral view of this species. Upper Coldwater. Point aux Barques lighthouse.

Figs. 11, 12. *Camarotœchia camerifera* A. Winchell. Lower Marshall. Valley of Willow river. Huron City, Michigan.

Figs. 13, 14. *Eumetria polypleura* A. Winchell. Pedicle and brachial view of two individuals. Upper Coldwater. Point aux Barques lighthouse.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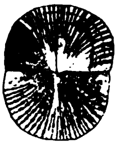
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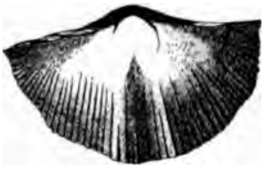
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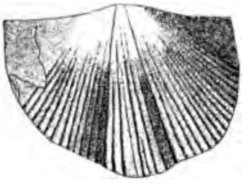
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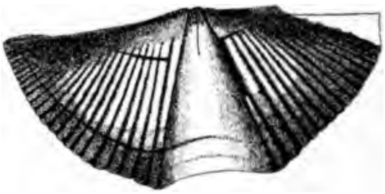
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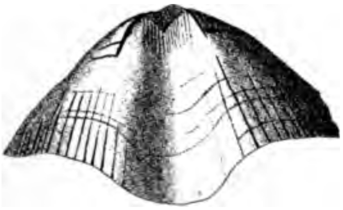
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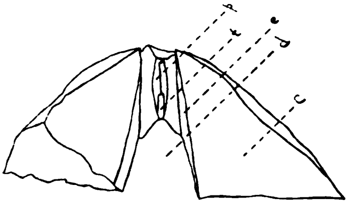

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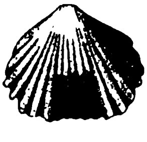
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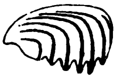
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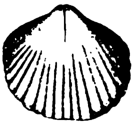
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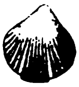
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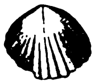
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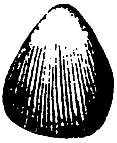
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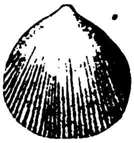
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W. F. Cooper, del.

DESCRIPTION OF PLATE XI.

Fig. 1. *Aviculopecten areolatus* n. sp. (Cooper.) Left valve showing the irregularly striated test. Upper Coldwater. . Point aux Barques lighthouse.

Fig. 2. *Leiopteria torreyi* Hall. Left valve magnified two times. Marshall group. Port Austin, Michigan.

Fig. 3. *Microdon reservatus* Hall. Left valve showing muscular impressions and connecting pallial line. Upper Coldwater. Valley of Willow river, two miles south of Huron City

Fig. 4. *Nuculites fallax* n. sp. (Cooper.) Left valve enlarged two times. Marshall group. Port Austin, Michigan.

Fig. 5. *Edmondia binumbonata* A. Winchell. Right valve of this form. Upper Coldwater. Point aux Barques lighthouse.

Fig. 6. *Sphenotus æolus* Hall. Right valve of a specimen of this species. Upper Coldwater. Point aux Barques lighthouse.

Figs. 7, 8. *Schizodus triangularis* Herrick. Left and right valve. Upper Coldwater. Point aux Barques lighthouse.

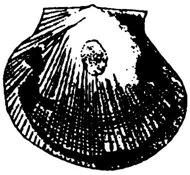
Fig. 9. *Schizodus binumbonata* A: Winchell. Right valve of a normal specimen. Upper Coldwater. Point aux Barques lighthouse.

Fig. 10. *Prothyris meeki* A. Winchell. Left valve showing a variable form of this species. Upper Coldwater. Point aux Barques lighthouse.

Fig. 11. *Sanguinolites borealis?* A. Winchell. Right valve magnified two times. Marshall group. Port Austin, Michigan.

Figs. 12, 13. *Sanguinolites michiganensis* A. Winchell. Right and left valve drawn two times. Marshall group. Port Austin, Michigan.

Figs. 14, 15. *Proetus missouriensis* Shumard. Head and tail of this form. Upper Coldwater. Point aux Barques lighthouse.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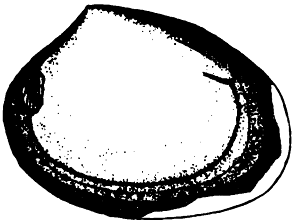
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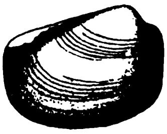
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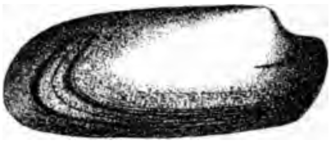
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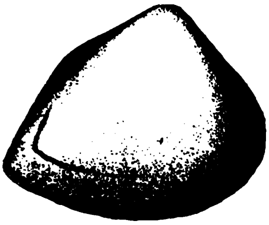
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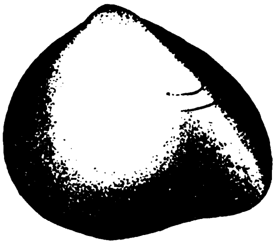
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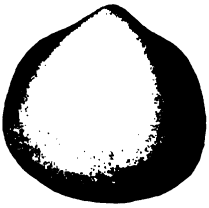
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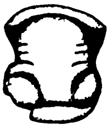
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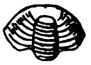
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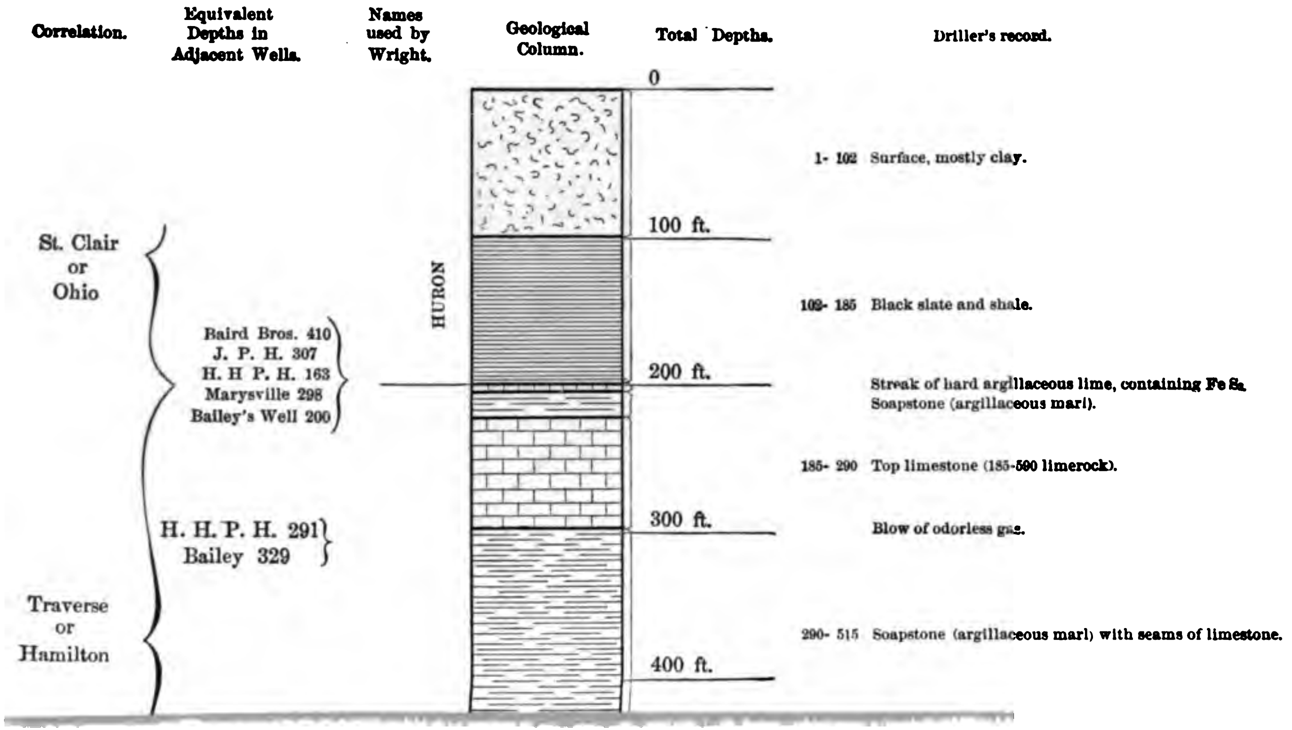
W. F. Cooper, del.

Plate LVII.

PORT HURON, No. 12.

St. Clair Co., Alt. 688 ft. to 589 ft.
F. L. Wells; begun Aug. 1st, 1886. Depth 1685 ft. +
Port Huron Daily Times, May 28th, 1887. C. E. Wright; with samples.


Correlation.
Equivalent Depths in Adjacent Wells.
Names used by Wright.
Geological Column.
Total Depths.
Driller's record.
St. Clair or Ohio
Traverse or Hamilton
Baird Bros. 410
J. P. H. 307
H. H P. H. 163
Marysville 298
Bailey's Well 200
H. H. P. H. 291
Bailey 329
HURON
0
100 ft.
200 ft.
300 ft.
400 ft.
1- 102 Surface, mostly clay.
102- 185 Black slate and shale.
Streak of hard argillaceous lime, containing Fe S₂.
Soapstone (argillaceous marl).
185- 290 Top limestone (185-590 limerock).
Blow of odorless gas.
290- 515 Soapstone (argillaceous marl) with seams of limestone.

GEOLOGICAL SURVEY OF MICHIGAN

ALFRED C. LANE, STATE GEOLOGIST

VOL. VII

PART III

GEOLOGICAL REPORT

ON

SANILAC COUNTY

MICHIGAN

BY

C. H. GORDON

ACCOMPANIED BY FIVE PLATES AND TWO FIGURES
INCLUDING ONE COLORED MAP

PUBLISHED BY AUTHORITY OF THE LAWS OF
MICHIGAN
UNDER THE DIRECTION OF
THE BOARD OF GEOLOGICAL SURVEY

LANSING
ROBERT SMITH PRINTING CO., STATE PRINTERS AND BINDERS
1900

Entered according to Act of Congress in the year 1900, by

Governor Hazen S. Pingree

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OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN, Sept. 15, 1900.

To the Honorable, the Board of Geological Survey of Michigan:

HON. HAZEN S. PINGREE, *President.*
HON. PERRY F. POWERS.
HON. JASON E. HAMMOND, *Secretary.*

GENTLEMEN—Herewith I transmit as Part III of Vol. VII, a report by Dr. C. H. Gordon containing the results of his examination of Sanilac county in the summer of 1896, together with a few data since received.

This report is much shorter than the two previous parts of this volume. I do not intend to pad the county reports to make them of equal size. In the case before us the exposures of bed rock, and the deep wells of this county are much fewer than in Monroe or Huron counties, and there has been less development of the resources. Its shales, especially, deserve further attention. Moreover some general matters have been treated of in Part I and Part II, and need not be repeated here.

Finally Dr. Gordon has been absent from the State and not able to give as much recent revision, as he otherwise might.

Permit me to call attention to the fact that the three parts of this volume together cover all the rocks of the Lower Peninsula, so that no matter where one may dwell therein, he will find in this volume descriptions which will be more or less applicable to his home.

With great respect I am your obedient servant,

ALFRED C. LANE,
State Geologist.

TABLE OF CONTENTS.

CHAPTER I.

INTRODUCTION.

Page.
§ 1. Location and dimensions 1
§ 2. Industries 1
§ 3. Vegetation and animals 1
§ 4. Towns, railways 2
§ 5. Previous geological work 2

CHAPTER II.

PHYSIOGRAPHY.

§ 1. Topography 3
§ 2. Altitudes 4
§ 3. Drainage 5

CHAPTER III.

STRATIGRAPHY.

§ 1. The Coldwater shales 7
Valley Center well 11
Croswell well 11
Papst well 12
§ 2. Marshall sandstone 12
§ 3. Pleistocene deposits 13
The Port Huron-Saginaw Moraine 13
Detroit Moraine 14
Overwash Plains 14
Esker (Hogback) 14
Glacial Drainage and Delta Deposits 15
Pebbleless Clays 16
Lake Beaches 16
Belmore Beach 17
Forest Beach 17
Boulder Walls 18

CHAPTER IV.

ECONOMIC GEOLOGY.

§ 1. Coal 21
§ 2. Building stone 22
§ 3. Grindstone 22

Page.
§ 4. Shales 22
§ 5. Marls 22
§ 6. Clays and clay industries 23
Drift clay 23
Lacustrine clay 23
Brickyards 23
§ 7. Soils 25
§ 8. Water supplies, wells 25
Sandstone wells 26
Shale wells 26
A partial list of rock wells—sandstone wells 28
A partial list of rock wells—shale wells 30

LIST OF ILLUSTRATIONS.

PLATES.

I. Port Huron well, No. 12 (reprinted) .... Faces title.
II. Cross-sections of Sanilac county from east to west ....page 6
(a) Through Port Sanilac and Carsonville.
(b) Through Deckerville and Novesta.
III. (a) Shale outcrops near Forestville 10
(b) Shale near White Rock about 2½ miles north of Forestville.
IV. View of the "Stone wall," near Cass City 18
V. Geological map of Sanilac county ....End.

FIGURES.

Page.
1. General section of rock formations underlying Sanilac county 8
2. Cross-section of "stone wall," swamp showing conditions for formation of boulder walls by its expansion 18

Page.
§ 4. Shales 22
§ 5. Marls 22
§ 6. Clays and clay industries 23
Drift clay 23
Lacustrine clay 23
Brickyards 23
§ 7. Soils 25
§ 8. Water supplies, wells 25
Sandstone wells 26
Shale wells 26
A partial list of rock wells—sandstone wells 28
A partial list of rock wells—shale wells 30

CHAPTER I.

INTRODUCTION.

§ 1. Location and dimensions.

Sanilac county is situated on the eastern side of the Lower Peninsula adjoining the lower end of Lake Huron and is bounded on the north by Huron county, on the west by Tuscola and Lapeer counties and on the south by St. Clair county. It is a somewhat irregular parallelogram measuring in its greatest dimensions something more than forty-two miles from north to south and thirty from east to west, and embraces an area of about 972 square miles, or 622,080 acres. The banks of the lake forming the eastern boundary are on an average about 40 feet in height and afford a fine view of the lake.

§ 2. Industries.

Formerly the county was heavily timbered with white pine which was run down the Cass and Black rivers to Saginaw and Port Huron respectively, or manufactured into lumber on the lake shore. These supplies, however, are now exhausted and agriculture is the principal industry. The soil of the county is generally fertile, consisting mainly of sandy and clay loams overlaid by a variable thickness of vegetable mold, and produces abundant crops of wheat, hay, oats, barley, peas and potatoes. Over a large area in the central part of the county this mold is especially thick, this region being until recent years mainly an uninhabitable swamp. Drainage, however, is effecting notable changes in the region and the lands thus being reclaimed are destined to constitute the richest agricultural lands of the district.

§ 3. Vegetation and animals.

In addition to white pine, the county was originally heavily timbered with cedar, hemlock, maple, beech, oak, ash, elm, basswood and hickory with an occasional balm of Gilead and cottonwood, while tamarack covered the more inaccessible portions of the swamps. Of the natural fruits blackberries and whortleberries were abundant in certain parts, while raspberries (black and red), strawberries, various kinds of wild cherry, wild plums, and the crab apple were plentifully distributed.

The forest abounded in wild game such as elk, moose, deer, bear, wolf, lynx, fox, otter, beaver, mink, marten, raccoon, muskrat, wild turkey, ducks and other small fowl. The country was remarkably free from reptiles, there being found only the small striped snake, *Eutænia sertalis*, water snakes of several kinds, *Trepidonotus*, and the light spotted snake commonly called milk snake, house snake, or spotted adder, *Oppibolus, doliatus var. triangulus*, and rarely a small rattle-snake, the massasauga, *Caudisona catenata*.

§ 4. Towns, railways.

The most important towns are Croswell, Brown City, Marlette and Port Sanilac. The population of the county according to the census of 1890 was 32,589.

The only railway which traverses the county is the Port Huron & Northwestern, absorbed in the Pere Marquette system. One division, the Port Austin, a narrow gauge road, traverses the county from north to south following the left bank of the Black River, while the Port Huron division, a broad gauge road, intersects the southwestern corner of the county.

§ 5. Previous geological work.

No records exist to show that any geological work has ever been done in the county, the absence of rock exposures and of prominent geological features being evidently the reason for this apparent neglect. That it is not wholly wanting in features of interest geologically, however, will appear in the following pages.*

Acknowledgments.—The author acknowledges indebtedness for many favors received during the progress of the work. Thanks are especially due G. Schraeder, and D. Reynolds, well drillers, for records of wells and to many others for various courtesies and favors.

---

*Since this was written there has appeared in the Bulletin of the Geological Society of America, Vol. 8, a paper by F. B. Taylor on the Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan, which deals mainly with observations made in Sanilac and adjoining counties.

CHAPTER II.

PHYSIOGRAPHY.

§ 1. Topography.

The larger part of the county consists of a plain with an average elevation of about 200 feet above the level of Lake Michigan, and bounded on the east, north, and west by morainic hills ranging from 60 to 100 feet above the general plain level. An isolated area of similar knobby topography also occupies the south central portion of the county in the vicinity of Melvin.

The eastern boundary of the plain is marked approximately by the Harbor Beach Railway which follows the base of the ridge from Palms to the southern boundary of the county. From Palms the range of hills swings around to the west and southwest crossing over into Tuscola county, extending southward through Tuscola and Lapeer counties just outside the limits of Sanilac. A spur or outlier of this range of hills occurs two miles southwest of Brown City and is known locally as the "Mountain." The elevation of this morainic ridge varies from 20 to 100 feet above the level of the interior plain. The greater part of the interior plain is imperfectly drained and until recent years was covered with swamps. The swamp area has been rapidly encroached upon of late and at the present rate of progress a few years more will see the whole under profitable cultivation.

On the east, the plain is drained by Black River emptying into Lake Huron at Port Huron, and on the west its waters find their outlet by Cass River into Saginaw Bay. The plain surface is relieved here and there by ridges and hills of sand representing marginal deposits of the lake which formerly occupied the region. Its elevation above the lake level varies from 150 feet at the south to 200 feet at the north. The belt of hills constituting the eastern boundary of the "swamp area" varies in width from four or five miles at the north to less than one mile at the southern boundary of the county. The surface of this belt represents a somewhat irregular plateau level except as modified by lateral drainage, chiefly lakeward, and has an elevation of nearly 300 feet above lake level at the north, descending gradually toward the south to about 180 feet. From Minden to Croswell the descent is very gradual not exceeding 60 feet, or less than three feet per mile. South of this the descent is more rapid and the ridge is scarcely observable a few miles south of the boundary of the county. At Amadore, the ridge has been intersected by lateral drainage so as to form a natural outlet for the railroad which at this point passes to the eastern side. The moraine belt consists of two or more simple ridges, the one along the western margin being the higher. East of the moraine, the surface descends uniformly from the base of the ridge to the margin of the lake where the bluff has an average height of about 40 feet. The surface is trenched by numerous short streams which flow in narrow steep sided channels. The average width of this plain is about five miles with an eastern slope of 25 to 30 feet per mile.

Old beach lines representing successive stages of lake subsidence occur at various distances from the present shore. The highest and most prominent of these is the Charleston Beach* which is well developed at Charleston Post Office and near Amadore. At the former place it is about 170 feet, and at the latter 145 feet above lake level.

The surface of the northern townships, Minden, Austin and Greenleaf, is marked by the rolling topography characteristic of morainic regions. Along the southern border of the moraine in Minden and Austin townships, the hills are lenticular in shape and lie with their longer axes in a general north-south direction. A prominent hill of this type occurs about 1¼ miles east of Tyre in the S. E. ¼, Sec. 6, Minden township. It is about 1½ miles long in a N. W. and S. E. direction and ½ to ¾ of a mile broad. It has an elevation of about 85 feet above the marsh which surrounds it on all sides. It is canoe shaped with steep slopes at the sides and tapers out gradually at the ends.

§ 2. Altitudes.

Following is a list of known altitudes as shown by the profiles of the branches of the Pere Marquette R. R. which traverse the county:

---

*Gilbert who visited this region in 1896 identifies this as the Forest Beach.

PORT AUSTIN DIVISION.

	Distance from Port Huron, miles.	Elevation above Lake Huron.	Elevation above sea level.
Port Huron, North street	0	55	637
Old crossing G. T. R. R. crossing		10	692
Grant Center	15	163	745
*Jeddo	17	160	742
Amadore	20	182	764
Croswell	26	150	732
Anderson	32	157	739
Carsonville	38	185	767
Wilber Road		190	772
Deckerville	46	197	779
Cooley Road		213	795
Palms	52	231	813
Minden	56	237	819
*Harbor Beach†	70	18	600
Tyre	60	200	782
*Ubly†	68	204	786
*Badaxe†	70	170	752

† See report on Huron county.

PORT HURON DIVISION.

	Distance from Port Huron, miles.	Elevation above Lake Huron.	Elevation above sea level.
*Port Huron, old crossing G. T. R. R. grade		10	592
*Brockway Centre (Yale)	25	215	797
Melvin		245	827
York Station (Valley Center)	33	220	802
Brown City	37	230	812
Index		255	837
Marlette	45	260	842

* Not in the county.

Numerous aneroid readings were taken in the progress of the field work and from the data thus obtained the accompanying topographical map was prepared. This collection of data is not complete enough for the preparation of a map that will bear close inspection as to details. It will be found serviceable, however, as showing in a general way the topography of the county.

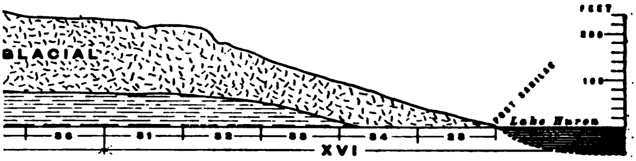
§ 3. Drainage.

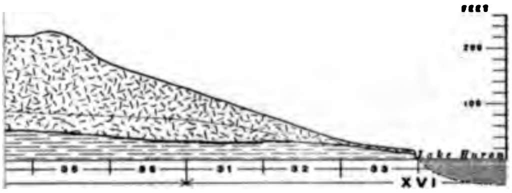
The drainage of the larger part of Sanilac county is effected by the Black and Cass Rivers, the former flowing southward and then eastward into Lake Huron, the latter westward and northward into Saginaw Bay. Black River rises in the southern part of Huron county, and flowing southward bearing eastward, follows along the western base of the morainic ridge to the southern line of the county in the western part of Worth township. In the southern part of the county, the river flows in a deep channel with precipitous slopes of boulder clay marked locally by deposits of stratified sand. The most important tributary of Black River is Elk creek which rises in the southwestern part of the county and after flowing northeastward enters Black River about 2½ miles southwest of Carsonville.

Cass River takes its rise in several branches which drain the western portions of the swamp which originally occupied the interior of the county. Formerly the drainage of this large area was but imperfectly effected by these rivers but it is now being improved by ditching.

The area east of the crest of the morainic ridge is drained by numerous short streams for the most part dry in summer, which flow directly into the lake. These flow in deep steep-sided channels the width of which, though unimportant, is sometimes great in proportion to the size of the stream.

Vol. VII Part III (Sanilac County) Plate II





NIV. OF

CHAPTER III.

STRATIGRAPHY.

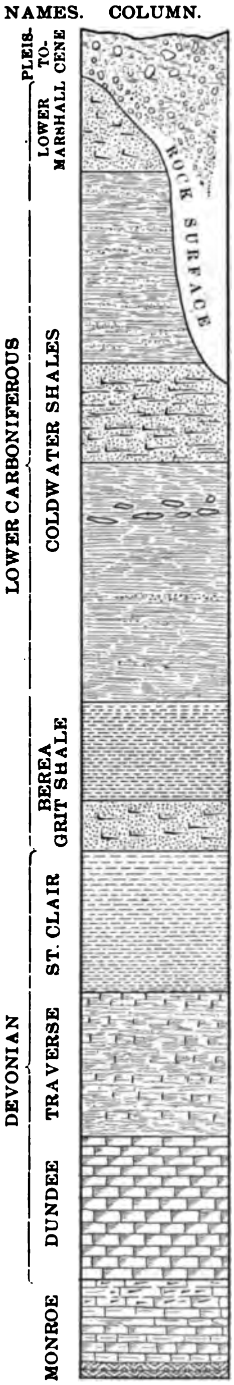
§ 1. The Coldwater shales.

The only indurated rocks appearing at the surface within the limits of the county are sandstones and shales belonging to the Marshall group, and the underlying Coldwater shales. Exposures are few and confined entirely to the northern portion of the county. Numerous wells have been drilled to the rock, however, and from the records thus obtained the surface area of the sandstone as shown in the cross sections, Plate II, and on the map Plate V, has been determined with a considerable degree of confidence.

The relation of these rocks to the underlying formations as determined from a study of exposures, and well records may be seen by comparing the general rock section of the county (Fig. 1) with the Port Huron section (Plate I), which we reprint from Volume V. As shown in that section the rock immediately underlying the drift belongs to the St. Clair formation.

The shales of the Coldwater formation constitute the oldest rocks observed in place within the limits of the county. Their surface area underneath the drift is to be found to the east of the boundary of the sandstone. One outcrop of the formation occurs on the lake shore near Richmondville and another near Forestville, (Plate III.) Three hundred paces south of the landing at Richmondville ten feet of shales outcrop in a vertical escarpment at the water's edge.

The shales are blue, thinly laminated and contain occasional thin beds of sandstone. The sandstone is fine grained, blue, and micaceous The layers of sandstone vary from a fraction of an inch to two or three inches in thickness. The exposure extends for half a mile along the shore. The only fossils observed were indistinct markings and casts. These shales are similar to the beds of the same formation used in Branch county for the manufacture of cement. About two miles south of this point, rock appears under water along the



THICKNESS.	CHARACTER.
0 ft. to 200 ft.	Glacial and recent; sand, clay, till
60 ft. to 100 ft.+	Sandstone
	Grindstone quarries
100 ft. to 200 ft.	Blue shales
	Forestville
50 ft. to 80 ft.	Sandstone
	Richmondville
200 ft. to 250 ft.	Blue shales
50 ft. to 150 ft.	Black shales
30 ft. to 50 ft.	Sandstone
100 ft. to 150 ft.	Shales, darker below
100 ft. to 150 ft.	Blue calcareous shales, and limestones, frequently dolomitic
125 ft. ±	Limestone
800 ft. ±	Dolomite, calcareous and argillaceous marls, anhydrite and rock salt

Fig. 1. General section of rock formations underly[illegible] county.

shore. At this point it is more decidedly arenaceous, the sandstone occurring in layers about six inches thick. The sandstone exposed here, known as the Richmondville sandstone, was correlated with the Berea sandstone of the Ohio reports in Volume V of the Michigan Geological Reports.[*] This is clearly an error as the rocks exposed at Richmondville can not be lower than the middle of the Coldwater shales and are probably within 100 or 200 feet of the top of that formation. It has been found that a bed of sandstone occurs at about this horizon in brine wells, and sometimes yields a brine comparable to that from the Berea. Several wells in the western part of the county show the presence of arenaceous beds at depths varying from 40 to 130 feet below the top of the shales and the Richmondville formation is evidently the equivalent of some of these. At White Rock, the Berea is found at a depth of from 495 to 555 feet.[†] The top of the White Rock well is about on a level with the top of the exposure at Richmondville. The distance between the two places is 12 miles. It would therefore require a rise of 40 feet per mile and more to bring the rocks to the surface at Richmondville.[‡] At Port Hope, 16 miles north of White Rock, the Berea is only 237 feet deeper, showing a dip of only 15 feet per mile between these points. At Forestville four miles south of White Rock the Berea was reached at a depth of 465 feet showing that the southward rise of the beds does not exceed 20 feet per mile. At Port Huron the borings show the surface rock under the drift to be the black shale immediately underlying the Berea sandstone. The distance between Richmondville and Port Huron is about 40 miles. It is evident that a dip of 40 feet per mile would bring to the surface at Port Huron rocks much lower in the scale. The record of the Croswell well (p. 11) indicates the presence of the Berea at 105 feet below the level of the lake. The distance in a north-south direction between Forestville and Croswell is 26 miles. The vertical distance between the positions of the sandstone in these two places is 360 feet showing a uniform rise of 14 feet per mile. The correspondence in dip in all these cases confirms the identification and shows that if not removed by erosion, as it is, or affected by a change of dip, the Berea would outcrop at the lake level about five or six miles south of Lexington.

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[*] 1881-1893, p. 78.

[†] Mich. Geol. Sur. Vol. V., pp. 58, 86.

[‡] Loc. cit., p. 76.

The exposure at Forestville was examined by Professor Ries who writes as follows concerning it: "Excellent exposures of Coldwater shales occur along Lake Huron at Forestville but they have not yet been utilized. The shale forms a line of cliffs and when fresh appears brittle and gritty. In places, however, it has mellowed down to a tough clay." The Forestville outcrop represents an horizon somewhat higher in the series than that at Richmondville and is characterized by a diminution in the amount of arenaceous material. Plate III is from photographs taken by Professor Ries at this point.

For a distance of five or six miles away from the margin of the Marshall sandstone, wells reach the shale at depths varying from 50 to 100 feet. E. Seaman's well (No. 2) (N. W. ¼, Sec. 7, Delaware township) is evidently just at the margin of the sandstone, as the drill appeared to penetrate a thin seam of broken sandstone underlain by the shale. East of a north and south line passing through this point, the wells show that the drift is underlain by shale yielding a brackish water. At Frederich's less than a mile southeast of Seaman's, the shale is reached at 60 feet. Two holes were put down here (Nos. 52 and 53) one of which extended into the shale to a depth of 225 feet, the total depth of the well being 285 feet. At Deckerville, Dr. Alderton's well (No. 62) reached shale at 90 feet while Renelt's well (No. 29) at the station shows a cavernous sandstone at 46 feet from the surface. The distance between the two wells is three-fourths of a mile and the difference in elevation at the surface is about 60 feet. At the Sanilac Stock Farm (No. 69) shale with brackish water was encountered at a depth of 37 feet.

At Brown City a well at the Harrington Hotel (No. 78) was said to have reached a depth of 212 feet without penetrating the full thickness of the drift. Lane's well (No. 76) on Section 16, Flynn township, reached what was taken to be a soft broken sandstone at 240 feet but doubt is expressed as to the character of the rock. The land surface here is about on a level with the rock surface at Marlette. A boring now (Jan. 1900) in operation at Valley Center has reached a depth of 685 feet with the following record: (Elevation 220 A. L., 800 A. T.)

(a) SHALE OUTCROPS NEAR FORESTVILLE.

(b) SHALE NEAR WHITE ROCK, ABOUT 2½ MILES NORTH OF FORESTVILLE.

Valley Center Well:

	Driller's record.	Thickness, feet.	Total	
1.	Red sand loam	5	5	Glacial, 149.
2.	Quicksand	90	95	
3.	Clay	22	117	
4.	Sand and gravel, with plenty of pure water	32	149	Coldwater, 390.
5.	Sandstone	5	154	
*6.	"Conglomerate"	20	174	
7.	Sandstone	30	204	
8.	"Slate" (blue shale)	10	214	
9.	"Soapstone" (blue shale)	175	389	
10.	"Slate"	150	539	
11.	"Limestone"	10	549	Berea, 30.
12.	"Grindstone"	20	569	
13.	"Slate" (blue shale)	116	685	St. Clair, 116.

*Note.—While these beds (5, 6, 7) presumably belong to the Coldwater series it is not improbable that they represent the lower portion of the Marshall sandstone. A consideration of the dip, however, would seem to indicate that the base of the Marshall sandstone if this formation were present, would be sixty to one hundred feet above the rock surface. (No. 5.)

The first indurated rock (sandstone) penetrated by the drill in this well corresponds to the Richmondville sandstone.* The Berea, here showing no evidence of gas, was reached at a depth of 539 feet.

The well for the Croswell waterworks (No. 79) shows a thickness of 190 feet of drift to which must be added 25 feet, as the well is located in the valley that much below the level of the station. The first rock reached in the Croswell well was black shale, probably representing the lower portion of No. 10 in the Valley Center well.

According to Mr. Marquette, the record of the water works well at Croswell is as follows: (Elevation at the top of the well 125 A. L., 705 A. T.)

Croswell Well:

		Thickness.	Total.	
1.	Clay and hard pan	20	20	
2.	Sand and gravel	170	190	
3.	Black shale	40	230	
4.	Limestone	20+	250	Berea.*
5.	Sandstone	425	675	
		675		

* Probably includes a part of No. 5.

The complete record of this well was not preserved and some doubt is to be entertained as to the correctness of the above figures, especially of No. 5 which with the exception of the upper 20 or 30 feet probably represents the St. Clair and Traverse shales. A test boring 100 feet deep was made at this place a number of years ago but no record of this could be obtained.

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*Compare also, however, the sandy layers at Rock Falls, in Huron County.

Mr. R. Papst kindly furnishes the following record of a test well put down by him on his farm three miles south of Lexington. The well is located on the flats of Mills Creek 60 rods from the lake shore. (Elevation 20 A. L., 600 A. T.)

Papst Well:

	Thickness.	Total.
1. Hard clay	50	50
2. Quicksand	60	110
3. Gravel (flowing well)	42	152
4. Shale	136	288
5. Dark shale	17	305
6. Unknown (stopped in sandstone)	595	900
	900	

The first rock reached in this well belongs to the Saint Clair shales and represents an horizon probably 20 or 30 feet below the top of the formation.

A boring at Blaine, a station on the Port Austin Division of the F. & P. M. R. R. a few miles south of the southern boundary of the county, was still working in drift at a depth of 220 feet at the time of our visit.

§ 2. Marshall sandstone.

As shown on the accompanying map, Plate V, the Marshall sandstone underlies about three-fifths of the county. Within the boundaries as defined, wells generally reach rock at depths varying from twenty to sixty feet, though in some cases the depth to rock is 125 feet or more. The greatest thickness of the overlying mantle of drift is found in the vicinity of Minden. West of the moraine, rock may be found almost anywhere at a depth of 20 to 40 feet.

The only exposures of the sandstone observed are in the townships of Austin and Greenleaf. At Tyre the sandstone outcrops over a considerable area in the vicinity of the railroad station. The attempt was made some years ago to quarry the rock here for shipment to Port Huron and elsewhere, but it was found to be too soft for building purposes and the enterprise was abandoned.

In the northwest ¼ of Sec. 17, Austin township (T. 14, N., R. 13 E.) in the valley of the Tyre branch of the Cass river, the rock is exposed by stripping. The sandstone here is blue with an even, moderate fine grain, and resembles the same beds quarried for grindstones at Huron City. The making of grindstones has been carried on here on a small scale but the beds have not been sufficiently exposed to determine whether their character and extent are such as to warrant more extensive working. About two miles west of this point, the sandstone crops out in the road a short distance east of the Holbrook post office. At this point the rock appears to be coarser.

The area underlain by the sandstone as shown by well records is approximately as represented on the accompanying map. Its maximum thickness within the limits of the county has not been ascertained as no wells are reported to have extended through the beds except along the attenuated margin. The greatest thickness is shown by a test hole put down at Tyre. This hole started in sandstone at the surface and, at the time of our visit, had reached a depth of 90 feet said to be all in sandstone.

§ 3. Pleistocene deposits.

The Port Huron-Saginaw Moraine—This represents the last land-laid moraine of the Huron ice lobe and lies close to the east side of Black River all the way northward from a point five or six miles north of Port Huron. Near Ubly in the southern part of Huron county it joins a similar moraine that trends southwest through the northwestern part of Sanilac county and thence around the head of Saginaw Bay. The salient thus formed by the two moraines comprises a considerable portion of the county and is occupied by the Black River swamp. The moraine is wider and higher at the north diminishing both in width and height southward. It is made up of two or three parallel ridges from one to one and one-half miles apart, that on the west being the highest. The height of the moraine is from 80 to 100 feet above the level of Black River at the north, descending to about 30 to 40 near Croswell. The surface of the moraine belt is rolling and is marked by rather abrupt slopes on either side. In the vicinity of Tyre the southern border of the moraine is characterized by isolated lenticular hills lying with the longer axis extending nearly north and south. Boulders are abundant in this vicinity, in places being scattered over the marshes as well as the adjoining uplands. The lenticular hills have an abundance of boulders, often of large size, scattered over their surface.

The slope east of the moraine is occupied by lacustrine clay with occasional belts of sand representing former halting stages in the recession of the lake shore.

Detroit Moraine.—In the southern part of the county in the vicinity of Melvin is an isolated area of kames and kame moraines representing the northern extremity of the Detroit moraine. They consist of an aggregation of rounded hills of smooth flowing outlines (mammillary hills of Chamberlin). The central mass is made up chiefly of moraine deposits while the marginal portion is made up of hills and ridges of kame deposits, viz., hills and ridges of sand and gravel evidently deposited in the recess in the border of the ice lobe. One of these kame ridges extends northwest from Moore's Corners (N. E. cor., Sec. 22, T. 19 N., R. 14 E.) for a distance of several miles. In Washington township a well developed ridge occupies the angle between Elk Creek and Black River. Taylor* who visited this locality in 1896 observed a well marked beach on its eastern slope at an elevation of about 190 feet, which he identified as the Belmore beach. A low ridge or beach extends northeastward from Peck that may connect with the one just described. Another kame area occurs north of Peck and an isolated ridge was seen four miles west of Croswell. Similar sand ridges occur also east of Marlette.

Overwash Plains.—Adjoining the moraines in places occur plains of varying extent covered with overwash sand and gravel derived from the melting glacier. One well marked plain of this character occurs at the west foot of the Port Huron-Saginaw moraine near Carsonville. Something of this overwash character is seen also along the top of the moraine toward the south, where the subdued character of the moraine indicates that it was waterlaid. North of Marlette in Lamotte township the upland plain is covered by overwash in which gravel plays a conspicuous part.

Esker (Hogback.)—In the southern part of Lamotte township, extending across sections 33 to 36 inclusive, occurs a narrow sharp ridge of gravel known locally as the "Hogback." This ridge represents a type of glacial deposit known as the esker. It appears in the southeastern part of Section 36, extends westward bearing to the north across the sections named, then turns northward crossing the north line of Section 33 into Section 28 near the half section line.

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*Bulletin Geol. Society of America, Vol. 8, p. 40.

It is broken in places and at MacDonald post office, where it is intersected by the highway, it is 15 to 20 feet high and 80 feet wide at the base. In cross-section it is seen to consist of stratified sand and gravel of varying coarseness. In general the stratification planes conform to the surface, though more or less disturbed and broken at the lower sides. The gravel is often firmly cemented by lime and in places the layers of sand have become hardened by iron oxide into an incoherent sandstone.

The "Hogback" or esker probably dates from the time when this region was occupied by the glacier and represents the location of a glacial stream flowing in a channel within the ice. As the glacier melted away, the gravel filling the channel would settle down upon the land and being no longer contained by ice walls would naturally take the form now seen. The narrow serpent-like form and concentric stratification support this view of its origin.

Glacial Drainage and Delta Deposits.—The north fork of Cass River which flows through Greenleaf township takes its rise in two branches, one of which rises north of Ubly in Huron county, the other in the swamps south of Tyre. These streams are small and insignificant but occupy valleys of considerable width. The valley of the north branch and that of the fork below their junction is filled with gravel and several well marked terraces occur up to a height of 35 feet above the present stream bed. Above its junction with the south fork north and east of Cass City the valley has a width of several miles. In this vicinity two gravel terraces were recognized, one about 15-20 feet above the flood plain of the present stream, the second about the same height above the first. The first or Cass City terrace is one to two miles broad in places. These gravels belong to what is known as Valley Train deposits. No information could be obtained as to the depth of the gravel, but wells 25 feet deep do not pass through it. It is usually coarse, pebbles the size of walnuts and hens' eggs being abundant, and those of larger size frequent. The second terrace occurs only in remnants along the sides of the valley. It is found along the north side of the valley north and east of Cass City and along the north side of a flat topped ridge extending through Sections 30 and 31, Greenleaf twp., T. 14 N., R. 12 E. The elevation of the Cass City terrace is about 170 feet, thus corresponding with that of the Forest beach on the opposite side of the county. The evidence appears to support Taylor's* view that the gravel plain at Cass City may be a delta of the outlet of Lake Whittlesey, the name given to the body of water having for its limits the shore line represented by the Belmore beach. From Ubly to Cass City, the channel is from three-fourths to one mile wide. The floor of the channel is covered with great numbers of boulders.

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*Bulletin Geol. Soc. Am., Vol. 8, p. 41.

In Greenfield township (T. 14 N., R. 12 E.) a long narrow swamp extends from the eastern part of Section 13 southwestward to the southwestern corner of the township, and on across the south part of Cass River southward into Tuscola county. The swamp is separated from the valley of the north fork of Cass river on the north by a narrow ridge intersected at the southwest corner of section 15 by a small stream flowing into Cass River. This swamp called the "Stone wall swamp" connects with the valley of the east branch of north fork southeast to Holbrook post office and was evidently the outlet for the waters derived from the wasting glacier at the time the edge rested on the ridge along its northern side. This outlet Taylor calls the Cumber spillway and considers it to have been open only a short time during the active period of glacial recession and soon abandoned for the more important Tyre-Ubly channel now occupied toward the west by the North Fork of Cass River and toward the east by the upper part of Black River.

At the time the Tyre-Ubly outlet was active the drainage was evidently northward past Tyre, joining the Ubly channel about two miles below Ubly. The evidence of reversed drainage due to northward elevation is also well marked in the course of Elk Creek and the channel of Black River in the lower part of its course.

Pebbleless Clays.— Deposits of pebble-free stratified clay occur filling depressions in the surface of the moraine between Minden City and Deckerville and probably farther south. They are utilized for the making of brick at several places. At Weber and Ahner's brickyard in the southwest part of Section 19, T. 14 N., R. 15 E. the clay is eight feet thick, stratified throughout. For a depth of two feet the clay is blue, making a red brick. Below this the clay is of a dirty white or gray color and furnishes a light colored brick.*

Lake Beaches.—The strip of land varying from three to five miles in width between the moraine and the lake is marked by several belts of sand, representing former lake beaches. Between these the surface is flat with a pronounced lakeward slope. The surface deposit is a fine dark lacustrine clay.

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*"This is a wide spread phenomenon in the state and is probably due to the leaching of lime from the upper layers. Lime is usually present in clays in quantity sufficient to neutralize the coloring effect of the iron."—Lane.

Belmore Beach.—This is the highest beach recognized by Taylor within the limits of the county, and was found by him on the flanks of the kame ridge west and north of Abbotsford. We did not visit this locality but observed indications of shore lines at about the same elevation (190 feet A. L.) in the vicinity of Peck. In the vicinity of Cass City, Taylor observed a beach at about the same distance above the Forest Beach, viz., 20 or 30 feet, but this he identifies as the DuPlain Beach. If the Peck Beach has been correctly identified as the Belmore Beach, it would seem safe to correlate the Belmore and DuPlain beaches.

Forest Beach.—The most prominent beach is that passing through Charleston Corners in Delaware township. At this point it constitutes a ridge four to six feet above the general level and has an altitude here of about 170 feet above the lake. In Marion, Forestville and Sanilac townships the beach is not strongly marked but is well developed in Lexington and Worth townships. It constitutes a pronounced ridge one mile east of Amadore Corners. At this point its elevation above the lake as shown by the aneroid barometer is about 145 feet. This shows a northward rise of about 25 or 30 feet between this point and Charleston. This beach is known as the Forest Beach and represents the margin of a body of water which included much of the Huron basin, all of the Erie basin and a small part of the Ontario basin.* It has been traced to Badaxe where it bends southwestward and passes through Gagetown and thence through the northwest corner of Ellington township about six miles west of Cass City. From this point the beach extends to a point southwest of Vassar, returning thence along the south side of the moraine lobe to Cass City and beyond, around the head of a long narrow bay which is suposed to have occupied the valley of Cass River. The level lands and swamps occupying the valley of the county evidently represent the site of an ancient lake which must have had its outlet along the front of the ice toward the west. Scattered over this region occur sand areas, hills and ridges marked by indications of shore lines. These deposits are best developed in the marginal areas adjoining higher ground. In some cases the sand hills are evidently the product of wind agency and correspond to dunes now forming on lake shores.

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*It has been traced from Port Huron to a point opposite Richmondville by G. K. Gilbert of the U. S. Geological Survey and from there to Badaxe by F. B. Taylor. See Part I and Part II of this volume, on Monroe county and on Huron county.

Boulder Walls.—In Sections 31 and 32 Greenleaf township, along the margin of the stone wall swamp occurs a low stony embankment which has received considerable notoriety from its fancied resemblance to a stone wall and which has been quite widely heralded as evidence of an ancient civilization. The "wall" occurs in the swamp and was originally covered to a slight depth by vegetable mold. By the burning of the mold in the process of clearing the swamp a few years ago, the wall was exposed (Plate IV). It lies adjacent to the west margin of the swamp and parallel with it. Its distance from the margin is about 150 yards. The embankment has been exposed for a distance of half a mile or more and beyond this it has been traced for a considerable distance through the marsh by a line of stones which probably mark its site. In places the "wall" is low or absent entirely. The width of the embankment at the base is about 8 to 10 feet and it rounds to a broad apex. It is composed chiefly of glacial boulders of various sizes imbedded in a stiff blue clay. In places the interstitial material is a sandy marl supposed by those who regard the "wall" as the work of prehistoric man to be the crumbled mortar of the original wall. This material is greenish and of the same character as the marl underlying the rest of the swamp.* Immediately under the embankment the sand is packed quite hard for a depth of two or three inches as shown by excavation. The height of the "wall" is usually about 18 inches to two feet, though in places somewhat higher. A marked feature of the embankment is the presence of large stones scattered along the surface while the lower portion is made up almost entirely of smaller stones. Some of the stones at the top are two or three feet in diameter. A similar but less distinct embankment was observed adjacent to the east side of the marsh. It is said that like occur-

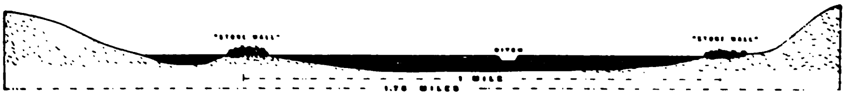

Fig. 2. Cross-section of "stone wall" swamp showing conditions for formation of boulder walls by ice expansion.

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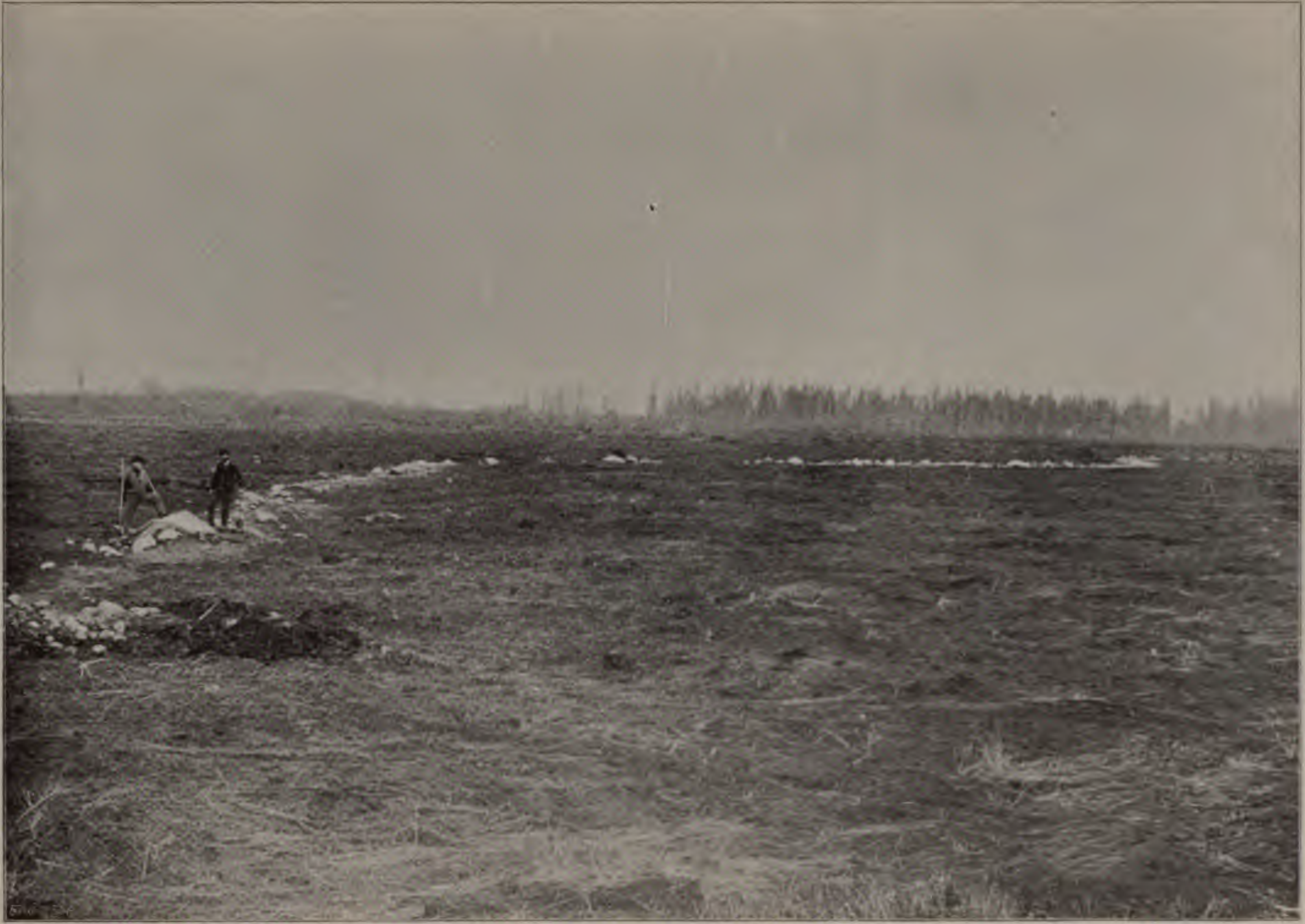
*A collection of this marl has been examined by Mr. Bryant Walker and found to contain forms slightly different from the present fauna. His report will be found in the report on Huron county (Part II of this volume p. 248).



VIEW OF THE "STONE WALL" NEAR CASS CITY.

rences have been noted at various points in Greenleaf and Austin townships, but no effort was made to verify the report. Various theories to account for the presence of these embankments abound locally most of which ascribe them to human agencies. The prevailing belief seems to be that they represent a fortification. Another theory is that they are the remnants of a former breakwater or levee. From a study of the physiographical and structural features of the region, however, it is evident that the "wall" is due to natural agencies. Three theories have been proposed to account for the embankment by natural agencies:

(1). That they represent constructive river terraces formed by flood waters derived from the melting edge of the glacier. (2) That they are due to englacial or subglacial drainage, and (3) That they represent the well known ice-beaches or boulder walls due to ice thrust found around the borders of many of our northern lakes. The last is the most probable explanation. After the opening of the Tyre-Ubly channel the diversion of the drainage left this as a long narrow lake or bay possibly connected with a larger body of water toward the southwest. Further evidence of the former existence of a lake here is found in the marl deposits underneath the vegetable mold. The ice forming over this shallow lake would enclose the boulders resting on the bottom and by its expansion would thrust them shoreward. So also floating ice under the influence of a strong wind has been known to drive boulders of considerable size upon a bank several feet in height and some distance back from the edge of the water. Prof. T. C. Chamberlin commenting on this as a probable explanation says this action is much more likely to affect large boulders than small ones and, besides, the fine material is washed out to a greater or less extent so that the coarse heavy boulders appear on the surface while finer material lodges in the mass under their protection.* From the configuration of the surface it is evident that the lake must have been shallow at the time these embankments were formed, so that in winter the water was frozen to the bottom for a considerable distance from the shore if not over the whole lake. Whatever was on the bottom, therefore, would be enclosed in the ice and thrust shoreward by its expansive force.

The Walled Lakes of Iowa which have received considerable notoriety from the popular belief that the embankments on their borders were the work of aboriginal inhabitants have been shown by White* to be due to ice thrust. He says, "It is true that the motion resulting from one winter's freezing would hardly be preceptible, but the act repeated from year to year, and century to century, would ultimately move everything upon the bottom beyond the reach of the ice. The tracks of the boulders thus moved have been observed, being as unmistakable in their character as those which the river mussel leaves behind it in the sand." * * * "Below the line of freezing the material would of course remain unmoved upon the bottom because there is nothing to disturb it."

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*Private letter to writer, dated Aug. 7, 1896.

"The real embankments are only found separating a piece of low land from the lake, because the material thrust out by the ice against the steeper banks merely accumulates there upon the slope which rises above any such accumulation, and also, of course above the high water line of the lake. In such cases the shore is thickly studded with boulders thrust against it, but the material meeting no such obstruction on a marshy side accumulates in circular ridges around the lake, and these are the walls which have excited so much wonder."

The observations hitherto recorded apply solely to walls around the borders of lakes. In the present instance the lake has long since disappeared and its site has become covered to a considerable depth by vegetable mold.

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*Geology of Iowa, 1870, Vol. I, p. 74.

CHAPTER IV.

ECONOMIC GEOLOGY.

§ 1. Coal.

The indurated rocks underlying Sanilac county are below the coal bearing formations of the state and there is, therefore, little probability of finding workable deposits of this valuable mineral. The Marshall sandstone sometimes contains a considerable amount of carbonaceous matter and wells sunk into this rock often pass through thin seams of coal. The well put down by E. Hunt (No. 24) in the S. E. ¼, N. E. ¼, Sec. 22, T. 14 N., R. 13 E. gave the following record:

	Feet.	Inches.
Sand and clay	49	......
Sandstone	27	......
Black coaly sandstone	..	6 to 8
Sandstone	..	4
Total	77	

The coal was immediately underlain by sandstone with no intervening clay deposit. Mr. J. Hunt's well (No. 23) one-fourth mile south of the preceding was said to have shown three feet of broken "slate," coal and gravel immediately below the drift with a 10 or 12 inch seam of coal beneath eight feet of sandstone. The full record is as follows:

	Feet.	Inches.
Sand and clay	29	......
Broken slate and coal	3	......
Sandstone	8	......
Coal, quite hard	..	10 to 12
Sandstone	19	
Total	60	

The water is said to be bad, having a strong petroleum-like smell when the well is not in constant use. A black, tarry, oily substance was found just above the coal. Such indications are not unusual in the sandstone belonging to the Carboniferous era and cannot be looked upon as having special significance.

§ 2. Building stone.

In places the boulders of the drift constitute the best available supply of building stone. The Marshall sandstone sometimes furnishes a suitable rock for caps and sills, though it is usually too soft to supply a durable stone. At Tyre an effort was made some years since to quarry the rock for use in buildings in Port Huron but owing to the softness of the rock the attempt was abandoned.

§ 3. Grindstones.

The sandstone is being quarried on a small scale for grindstones in the N. W. ¼ of Sec. 17, T. 14 N., R. 13 E., on the land of R. Cleland. The rock is exposed on the floor of the valley by removing a thin covering of surface material. The stone is blue and closely resembles that quarried at Grindstone City. Only a small opening has been made, the rock taken out being in comparatively thin slabs and fitted chiefly for small grindstones.

§ 4. Shales.

Shale is an indurated clay whose consolidation has been effected under the influence of pressure assisted more or less by cementation. Except as to hardness clay and shale are alike in their properties and have similar uses.

Ordinary clay products constitute the most important uses to which shale is put at the present time. In addition to these, however, shale is used for the manufacture of Portland cement, mineral paint and for road material. The Coldwater shales constitute the most important source of supply in the state for the manufacture of Portland cement and are extensively quarried for that purpose at Bronson, Union City and Coldwater.

Professor Ries says (Vol. VIII, Part I), "The shales of this series (Coldwater) show, so far as tests go, the properties desirable in the manufacture of vitrified wares. They also burn to a good red color and vitrify at a moderate heat." Samples of the shale from near Forestville and White Rock (just over the line in Huron county) have been subjected to tests by Professor Ries and the results appear in the report on Huron county, Part II, p. 208. If the indication of usefulness suggested by these tests is borne out in practical application the favorable exposures of the beds in Sanilac county offer possibilities of a profitable industry.

§ 5. Marls.

Marl of good quality occurs in some of the marshes but the extent of these deposits is not known. A deposit of this kind near Tyre has been utilized on a small scale for the manufacture of a scouring polish. It is made up mostly of broken shells which are reduced to a powder by grinding.

The most important use to which marl has been applied in this state is as an accessory ingredient in the manufacture of Portland cement, which is usually made from a mixture of shale and marl. "The essential elements of such cement are silica, alumina and lime, the first two of which are supplied by the shale and the last by the marl or limestone. The best results are obtained from a mixture in which the lime percentage is equal to 2.8 times the silica plus 1.1 times the alumina." (Prof. Ries.)

Should the Forestville shales prove suitable for the manufacture of cement the occurrence of sufficient supplies of marls within available distance will be a matter of considerable economic importance.

§ 6. Clays and clay industries.

Drift Clay.—As a rule the clay belonging to the drift deposits is unsuited for manufacturing purposes owing to the presence of pebbles especially of limestone, and boulders which interfere with the working. Occasionally however, a locality is found furnishing a drift clay that may be utilized when nothing better offers. This clay is worked on a small scale at Forestville and at one or two other places, but the brick made from it is of inferior quality.

Lacustrine Clays.—At several places the shallow depressions in the surface of the drift is found filled with a deposit of fine pebbleless clay varying in thickness from one to twelve feet and usually well stratified. These are evidently of lacustrine origin dating from the time the county was in large part under water. These deposits constitute the source of supply for the clay used by nearly all the clay working industries of the county and in general yield a good quality of clay for brick and tiling. In the eastern part of the county the deposit is composed of two or three feet of dark reddish clay yielding a red brick, while below this there are four to nine feet of whitish gray clay yielding a light colored brick. A mottled brick is made by mixing these together.

BRICKYARDS.

Weber & Ahner.—Brickyard is located in the S. W. ¼, S. W. ¼ of Sec. 19, T. 14, N., R. 15 E., on the land of Wm. McDonald. The clay is eight feet thick, consisting of two feet of dark blue clay above, underlain by six feet of whitish clay. The deeper portions are not worked owing to the presence of water. The clay contains no lime nor pebbles and according to the proprietors does not shrink in burning. The output in 1896 was 600,000 brick. No tile is made. The machine used is manufactured by Kills & Son of Adrian. Michigan.

R. Wyers & Son.—Deckerville: This yard is located one mile east of Deckerville in the northeast corner of Section 32, T. 13 N., R. 15 E. The clay is twelve feet thick—three feet of dark clay underlain by nine feet of light colored clay. The output for 1896 was about 200,000 brick and 15,000 tiling. A Kills & Son's machine is used.

John Rumptz.—Croswell: Brickyard is located east of the railroad in the northeast corner of Section 29, T. 10 N., R. 16 E. The clay is 10 feet thick, dark above, light colored below. Common brick only are made. Output in 1896 about 300,000. A Kills & Son's machine is used. Mr. Rumptz also operates a yard at Minden the output being about 200,000 for 1896.

Riley Bros.—Carsonville: This yard is located on the east bank of Black river in the N. E. ¼, N. E. ¼ of Sec. 15, T. 11 N., R. 15 E. The clay is about 14 feet thick, stratified and rests upon quicksand. The upper dark clay is three and the lower white clay is eleven feet thick. The bed wedges out quickly toward the east where it abuts upon the western slope of the moraine.

It is overlain by a thin covering of sand. This yard is located on the east bank of the Black river just at the narrows between the kame ridge on the west and the Port Huron-Saginaw moraine on the east. Both common brick and tiling are made here, the output for 1896 being 300,000 brick and 40,000 tiling. A Kills & Son's machine is used.

John Large.—Brown City: Yard located about a mile southeast of Brown City in the S. E. ¼, N. E. ¼, Section 18, T. 9 N., R. 13 E. The surface clay here is about four feet thick and is utilized chiefly for common brick and tiling. Some pressed brick are made to fill orders. The output for 1896 was 400,000 brick and 100,000 tiling.

O. L. Ballard.—Marlette: Yard situated in the western part of the village. The clay occurs here in pockets of limited extent and has been nearly exhausted. The works will probably close at the end of this season. The clays of the drift underlying the pebbleless clays have been made use of to some extent, but more or less trouble is experienced from the presence of lime. The output for 1895 was 1,000,000 common brick and 60,000 tiling, and for 1896, 350,000 brick and 20,000 tiling.

§ 7. Soils.

The account already given of the Pleistocene deposits may be taken as an index of the character of the soils of the county. The area included in the Black River swamp is covered to a depth of one to several feet by a vegetable mold that under proper treatment will yield abundant crops. In the central portions where the mold is thick it is composed almost entirely of vegetable matter partially decomposed. On being drained and tilled this becomes dry and easily catches fire. Considerable areas are thus being burned over every year. If not thus destroyed, with further tillage the decomposition of the mold will become more complete and eventually yield a valuable soil. This process might doubtless be hastened by mixing with the mold some of the sand and clay soils from the uplands. Until it has reached a further stage of decomposition, however, the spread of the mold over lighter soils does not appear to be beneficial. The surface clays representing the water-laid deposits found over a considerable part of the county furnish an excellent soil, that yields abundant crops of hay, barley, corn, beans, peas, potatoes, etc. These areas occur east of the moraine and surrounding the swamps. The sand and gravelly soils found along the minor beaches are also valuable and readily worked. Adjoining the higher areas these lands are spread over with a thin layer of overwash sands and gravels which tend to enhance their value as soils. In some places, however, as south of Carsonville along the foot of the moraine, the overwash is abundant and furnishes a soil of much less value. Of still less value are some of the sandy soils found in some of the kame areas and among the duny sand hills. The commingling of sand and gravel in the kames associated with the moraines as at Melvin and elsewhere furnishes a fairly good soil. In the higher areas representing land-laid moraine deposits the soil is a boulder clay. These higher areas were the first brought under cultivation, and are generally occupied by old and well cultivated farms.

§ 8. Water supplies, wells.

Surface Wells.—In early days the water supplies were obtained from surface wells usually from 15 to 20 feet in depth and seldom over 40 feet. The drying up of the swamps has affected these wells and made necessary a deeper search for more permanent supplies. With this removal of the surface waters and the procuring of more palatable water there has been a marked decrease in the prevalence of fevers since the day when "chills and fever" was the common lot of the hardy pioneers who undertook to make for themselves homes on the islands surrounded by tangled swamps.

Sandstone Wells.—In areas underlain by the Marshall sandstone, this formation furnishes an inexhaustible supply of water of excellent quality. West and south of the Port Huron-Saginaw moraine it can be reached by drill at a depth of 20 to 40 feet. In the moraine belt there is to be added to this the thickness of the drift above the interior plain level, making a maximum thickness of about 150 feet in the more elevated portions. For the most part wells reach sandstone here at depths considerably less than this. The water usually rises to a considerable height in these wells but in one instance only is it known to flow out at the surface viz., at E. Seaman's (No. 2) about a mile east of Minden. This well reaches water at a depth of 73 feet (67 feet to rock). At G. Schweigert's (No. 1) about 200 yards west the water rises to within two feet of the top of the well.

Shale Wells.—Throughout a belt four or five miles wide bordering the area covered by the Marshall sandstone, water is found in a layer of sandstone four to six feet thick at a depth of 40 to 100 feet below the top of the Coldwater shales. The water obtained from this horizon is brackish and often unfit for use. Drilling in this area is therefore usually attended with very unsatisfactory results. At still greater distances from the border of the sandstone few attempts have been made to penetrate the great thickness of drift and these have met with failure. At Brown City (No. 70), the attempt was abandoned after reaching a depth of 212 feet. At Lane's (No. 71) Section 17, Flynn township, it was given up at 240 feet and at Dorland's (No. 71) Section 21, same township, at 126 feet.* In that portion of the county southeast of the belt above defined the great thickness of drift stands in the way of successful efforts to obtain rock wells. Moreover, even when successfully penetrated, as at Croswell, Marlette and Valley Center, the limited supply and brackish character of the water found within several hundred feet of the surface of these formations render such attempts to secure satisfactory supplies disappointing. In this region, therefore, the drift itself must be relied upon as the only available source of supply of potable water. These supplies occur in beds of sand and gravel which are without recognized order or arrangement, intercalated between beds of clay in the drift. As the county becomes older the superficial beds will be inadequate to furnish needed supplies, a result already felt in many parts of the region. By sinking the well to a deeper stratum, however, new supplies may usually be found. While it may happen that in places deeper water-bearing beds may be wanting, the variable character of the drift deposits makes it quite improbable that such beds are wanting over any considerable area and by changing the location of the well a short distance new beds may be reached. There is generally a heavy water bearing bed of gravel and sand resting upon the rock surface at the base of the drift. The water from this, as at Valley Center, rises to within a few feet of the top of the well.

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*The great thickness of drift here, if correctly reported, may indicate the presence of a buried river channel, a phenomenon not uncommon in Michigan.

A PARTIAL LIST OF ROCK WELLS IN SANILAC COUNTY.—SANDSTONE WELLS.

Owner.	Location.	Elevation above Lake Huron.	Total depth.	Depth to rock.	Character of rock.
	Delaware Township (14-15.)				
1. C. Schweigert	N. W. Sec. 7		72	60	Blue sandstone, thin, broken. Water comes within two feet of the surface.
2. E. Seaman	N. W., Sec. 7	195	73	67	Flowing well.
3. Weber & Ahner	S. W., S. W	240	111	91	Blue sandstone. Water came up within 26 feet of top.
4. Wm. O'Mara	N. W., S. W. Sec. 30	270	126	100	Sandstone?
5. James Donlon	N. W., N. W. Sec. 31	280	122	117	Sandstone?
	Minden Township (14 14.)				
6. D. Moore & Son (Woolen Mills)	200 paces S., N. E. cor. Sec. 11	260	110	88	Shaly sandstone.
7. Wm. Lloyd	180 p. N., S. E. cor. Sec. 2	265	123	110	Sandstone, Upper 6 to 8 ft. softer.
8. Canham & Ross (Roller Mill)	200 p. S., N. E. cor. N. W. ¼ Sec. 12	240	100	60	Sandstone.
9. Canham & Ross (store)	Near depot	240	72	60	Sandstone.
10. Norman Burley	N. E., Sec. 2	200	93	60	Soft, not tested.
11. John Fisher	N. E., cor. Sec. 9		55	50	Sandstone.
12. W. Fisher	N. W., N. E. Sec. 8		47	40	Sandstone.
13. John Pelot	S. E., S. W. Sec. 4		65	58	Sandstone.
14. Jas. Rezmack	N. E., N. W. Sec. 8		75	68	Sandstone.
15. Joseph Murdock	280 p. S., N. E. cor. Sec. 10	240	112	104	Sandstone.
16. Jno. O'Conner	N. E. cor. Sec. 11		150	135	Sandstone.
17. Wm. Donnor	N. E., Sec. 17		55	48	Sandstone.
18. A. Kolar, Jr	N. W., S. W. Sec. 16		60	50	Sandstone.
19. Chas. Postle	N. E., S. E. Sec. 17		35	30	Sandstone.
20. R. R. Well at Palms	20 p. S. Station	231	110	40	Sandstone.
	Austin Township (14-13.)				
21. Tyre Test Hole	At elevator near station	200	90		Sandstone. Micaceous at 60-70 feet.
22. T. Pollard	S. E., S. E. Sec. 22		33	25	Blue sandstone.
23. J. Hunt	N. E., S. E. Sec. 22		60	29	Sandstone 3 ft., Broken slate, coal and gravel on rock. Water bad.
24. E. Hunt	S. E., N. E. Sec. 22		77	49	Sandstone, 27. Coal 16-8 inches.
25. Robt. Gray	N. E., N. W. Sec. 21		84	60	"White marble." probably white sandstone.
26. J. S. Nesbitt	N. E., N. E. Sec. 30		84	65 to 70	Sandstone.
	Greenleaf Township (14 12.)				
27. H. N. Sanburn	S. W., Sec. 27		207	27	Sandstone, flinty.
28. J. McPhall	N. E., N. E. Sec. 34		60	30	Sandstone.
	Marion Township (13-15.)				
29. Renelt's (Deckerville Sta.)	S. W., S. W. Sec. 30	197	53	46	Sandstone. Drill dropped one foot.

	Wheatland Township (13 14.)				
30. S. A. Terpenning	S. E., S. E. Sec. 13		51	45	Sandstone.
	Argyle Township (13-13.)				
31. Various wells	About Argyle Postoffice			25 to 30	Sandstone.
	Evergreen Township (13-12.)				
32. J. McQueen	N. E., S. E. Sec. 11		75	45	Sandstone. "Hard rock."
	Custer Township (12-14.)				
33. County jail	S. E., S. E. Sec. 32	190	65	40	Sandstone.
34. L. Dadgerow	S. E., N. E. Sec. 31		82	44	Sandstone.
	Moore Township (12 13.)				
35. Elmer Hotel	S. E., S. E Sec. 33	200	60	38	Sandstone.
36. W. H. Dorman	S. W., S. W. Sec. 20		60	40	Sandstone. "Hard white rock on top."
	Lamotte Township (12-12.)				
37. Robt. Bedford	S. W., N. W. Sec. 32		35	23	Sandstone.
	Watertown Township (11-14.)				
38. C. Murphy	S. W., N. W. Sec. 16		68	37	Sandstone.
39. W. Niemeyer	N. W., S. W. Sec. 6		90	40	Sandstone.
40. A. Hall	N. W., N. W. Sec. 6		72	43	Sandstone.
41. F. Eggert	N. E., S. E. Sec. 18		40	20	Sandstone.
42. Robert's Hotel (Sanilac Center)	N. W., N. W. Sec. 4		72	36	Sandstone.
43. J. Kasdorf	N. W., S. E. Sec. 32		95	70	Sandstone. "Hard white rock."
44. J. Paton	N. W., N. W. Sec. 27		125	83	Sandstone.
45. A. S. Parks	N. E, S. E. Sec. 34		82	37	"Hard white rock."
46. Geo. Potten	S. E, N. E. Sec. 17		50	37	Sandstone.
47. J. Bartley	N. E., N. W. Sec. 17		62	37	Sandstone.
	Elmer Township (11-13.)				
48. O. F. Teeple	S. E., S. E Sec. 13		86	42	Sandstone. "Hard rock" 1 ft. Blue sandstone 20 ft.
49. Robt. Hall	N. E., S. E. Sec. 14		119	44	Sandstone.
	Marlette Township (11-12.)				
50. W. A. Ellis	N. E., N. E. Sec. 6		77	40	Sandstone.
51. E. L. Brown	N. E., Sec. 8 (9-13) Lapeer Co.		82	69	Sandstone. ("Grindstone.")

WELLS.

Owner	Location	[illegible]	[illegible]	[illegible]	Character of rock
	Delaware Township [illegible]				
W. Frederick	N. W. ¼ Sec. [illegible]		[illegible]	[illegible]	Shale. Water brackish
W. Frederick, second well	N. W. ¼ Sec. [illegible]		[illegible]	[illegible]	Shale. Water brackish
School house well	[illegible]		[illegible]	[illegible]	Shale
Wm. McDonald	[illegible]		[illegible]	[illegible]	Shale. Blue shale rock
W. H. Vaily	[illegible]		[illegible]	[illegible]	Shale
[illegible]	[illegible]		[illegible]	[illegible]	Shale
A. [illegible]	[illegible]		[illegible]	[illegible]	Shale
[illegible]	[illegible]		[illegible]	[illegible]	Shale
	[illegible] Township [illegible]				
Christian [illegible]	[illegible]		[illegible]	[illegible]	Shale
	Marion Township [illegible]				
[illegible] Anderson	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Gray shale
	Bridgehampton Township [illegible]				
[illegible]	[illegible]		[illegible]	[illegible]	Shale
	Custer Township [illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]		[illegible]	[illegible]	Shale [illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Water brackish
[illegible]	[illegible]		[illegible]	[illegible]	Shale
[illegible]	[illegible]		[illegible]	[illegible]	Shale
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]		No rock
Harrington House, Brown City	[illegible]	[illegible]	[illegible]		No rock
Cromwell waterworks	River bank 40 feet below railroad station	[illegible]	[illegible]	[illegible]	Not reached
Valley Centre	Near station	[illegible]	[illegible]	[illegible]	Sandstone [illegible]

GENERAL INDEX.

N. B.—The tables of wells and owners on pp. 28 to 30 are not indexed.

A.

Abbotsford 17
Aboriginal inhabitants 20
Acknowledgments 2
Adder 2
Agriculture 1
Ahner 16, 23
Alderton, Dr. H. F. 10, 30
Alumina 23
Altitudes 4
Amadore 4, 17
Aneroid readings 5
Animals 1
Area 1, 13, 25
Ash 1
Austin Township (T. 14 N., R. 13 E.) 4, 12, 19, 21, 22
  Section 17 12, 22
  " 22 21

B.

Badaxe 17
Ballard, O. L. 24
Balm of Gilead 1
Barley 1, 25
Basswood 1
Beans 25
Bear 2
Beaver 2
Beaches 4, 14, 15, 16, 17
Beech 1
Belmore Beach 14, 16, 17
Berea grit or sandstone 7, 9, 11
Blackberries 1
Black River 1, 2, 3, 5, 6, 13, 14, 16, 24
Black River swamp 25
Black shale 11
Blaine 12
Bluffs, average height of lake 4
Brick 16, 23

C.

Carboniferous 21
Carsonville 14, 24, 25
Cass City 15, 16, 17
Cass River 1, 3, 5, 6, 12, 15, 16, 17
Caudisona catenata 2
Cedar 1
Cement 7, 22, 23
Chamberlin, Prof. T. C. 14, 19
Channel in the ice 15
Charleston Beach 4
Charleston Corners 17
Charleston post office 4
Cherry, wild 2
Chills and fever 26
Clay 22, 24, 27
Clays and clay industries 23
  " of the drift 25
Cleland, R. 22
Coal 21
Coldwater, Mich 22
Coldwater shales 7, 9, 10, 11, 22, 26
Column, geological 8
Corn 25
Cottonwood 1
Crab-apple 2
Croswell 2, 4, 9, 11, 13, 14, 24, 26
Cross-sections 7, 15, 18
Cumber Spillway 16

D.

Detroit Moraine.................. 14
Deckerville.................10, 16, 24
Deer.............................. 2
Delta deposits.................15, 16
Delaware Township (T. 14 N.,
    R. 15 E.)........10, 16, 17, 23
    Section 7................. 10
    " 19..............16, 23
Devonian shale. (See St. Clair.)
Dip.............................9, 11
Dorland, Mr..................... 26
Drainage..................1, 5, 6, 16
Drift.......................7, 11, 27
Drift clay........................ 23
Ducks, wild....................... 2
Dunes............................ 18
Du Plain Beach.................. 17

E.

Economic geology................ 21
Elevations.....................3, 5
Elk................................ 2
Elk Creek..................6, 14, 16
Ellington Township............. 17
Embankments.................... 18
Englacial drainage............... 19
Erie basin.......................... 17
Eutænia sertalis.................. 2
Esker..........................14, 15
Exposures......................... 7

F.

Fauna............................ 18
Figures, 1.......................7, 8
    2.......................... 18
Flynn Township (T. 10 N., R. 13 E.)
    10, 26
    Section 16................ 10
    " 17................ 26
Forest Beach................4, 15, 17
Forestville.........7, 9, 10. 17, 22, 23
Fox................................ 2
Frederich, W...................10, 30
Fruits............................ 1

G.

Gagetown......................... 17
Gas................................ 11
Glacial formations......11, 15, 18, 19
Geological column. Plate I...... 8
Gilbert, G. K.......................4, 17
Gravel........................15, 27
Greenleaf Township (T. 14 N.,
    R. 12 E.)....4, 12, 15, 16, 18, 19
    Section 13................ 16
    " 15................ 16
    " 30................ 15
    " 31.............15, 18
    " 32................ 18
Grindstone City.................. 22
Grindstones....................13, 22

H.

Harbor Beach..................... 3
Harrington Hotel................ 10
Hay............................1, 25
Hemlock.......................... 1
Hickory........................... 1
Hills...........................3, 17
Hogback (Esker)..............14, 15
Holbrook post office...........13, 16
Hunt, E........................... 21
" **J.**.......................... 21
Huron basin...................... 17
Huron county.1, 5, 11, 13, 15, 17, 18, 22
" ice lobe.................... 13

I.

Ice-beaches....................... 19
Indurated rocks.............7, 11, 20
Industries........................ 1
Iron oxide........................ 15

J.

Jackson.........................36, 60
Jeff, Wm.......................... 60

K.

Kames..........................14, 24
Kills, A. & Son................... 24

L.

Lacustrine clay............14, 17, 23
Lake beaches..................16, 17
Lake Huron................1, 3, 5, 10
Lake Michigan.................... 3
Lake Whittlesey.................. 16
Lamotte Township (T. 12 N.,
    R. 12 E.).................. 14
Lane, A. C........................ 16

Lane's well....................10, 26
Lapeer county....................1, 3
Large, John.................... 24
Lenticular hills.................... 13
Lexington....................9, 12, 17
Lexington Township (T. 10 N., R. 16 E.).................... 24
Lumber.................... 1
Lynx.................... 2

M.

MacDonald post office.................... 15
McDonald, Wm.................... 23
Mammillary hills.................... 14
Maple.................... 1
Maple Valley Township (T. 9 N., R. 13 E.).................... 24
Section 18.................... 24
Marion Township(T. 13 N., R. 13 E.) 17, 24
Margin of ice.................... 13
Marl....................18, 19, 22, 23
Marlette....................2, 10, 14, 24, 26
Marten.................... 2
Marshall sandstone..7, 10, 11, 12, 13, 21, 22, 26
Marquette, Mr.................... 11
Massasauga.................... 2
Melvin....................3, 14, 25
Michigan Geological Survey....9, 18
Mills Creek.................... 12
Minden....................4, 12, 16, 24, 26
Minden Township, section 6.................... 4
Mineral paint.................... 22
Mink.................... 2
Mold....................1, 25
Moraines....2, 4, 12, 13, 14, 24, 25, 26
Mountain.................... 3
Moore's Corners.................... 14
Muskrat.................... 2

N.

Northern lakes, walls around.................... 19
North Fork, of Cass river.................... 16

O.

Oak.................... 1
Oats.................... 1
Ohio.................... 9
Ontario basin.................... 17
Ophiboluss doliatus var. **triangulus** 2
Organic matter....................21, 25
Otter.................... 2
Outcrop.................... 7
Outlets.................... 2
Overwash plains.................... 14

P.

Palms.................... 3
Papst, R.................... 12
Peas....................1, 25
Pebbles.................... 15
Pebbleless clay....................16, 23, 25
Peck....................14, 17
Pere Marquette R. R....................4, 12
Petroleum.................... 21
Physiography.................... 3
Pioneers.................... 26
Plain.................... 3
Plates, reference to—
" I....................5, 7
" II.................... 7
" III....................7, 9, 10
" IV.................... 18
" V....................7, 12, 17
Pleistocene deposits....................13, 25
See GLACIAL.
Plums, wild.................... 2
Population.................... 2
Port Austin.................... 2
" " Division of R. R.....5, 12
Port Hope.................... 9
Port Huron..1, 2, 3, 7, 9, 12, 13, 17, 22
" " Division of R. R.... 5
Port Huron & Northwestern R. R. 2
Port Huron-Saginaw moraine.13, 14, 24, 26
Port Sanilac.................... 2
Portland cement....................7, 22, 23
Potatoes....................1, 25
Prehistoric man.................... 18

R.

Raccoon.................... 2
Railways.................... 2
Raspberries.................... 2
Renelt's well.................... 10
Reptiles.................... 2
Reversed drainage.................... 16
Reynolds, D..................... 2
Richmondville....................7, 9, 10, 17
Richmondville sandstone.......9, 11

Ridge, 3, 17
Ries, H., 10, 22, 23
Riley Bros., 24
Road material, 22
Rock Falls, 11
Rock wells, 28
Rumptz, John, 24

S.

Saginaw, 1
Saginaw Bay, 3, 5, 13
Sand, 3, 17, 25, 27
Sandstone, 7, 9, 10, 11, 12, 13, 21, 22
" wells, 26, 28
Sanilac county, 1, 2, 3, 5, 13, 21, 22
" stock farm, 10
" Township, 17
St. Clair county, 1
" " formation, 7
" " shales, 11, 12
Salient, 13
Schraeder, G., 2
Schweigert, G., 26
Scouring-polish, 23
Seaman, E., well of, 10, 26
Shales, 7, 9, 10, 11, 22, 23
Shale wells, 26
Shore lines, 17
Silica, 23
Sistrurus tergeminus—Caudisona catenata.
Slate, 21
Snakes, 2
Soil, 1, 25
"Stone wall", 16, 17, 18
Strawberries, 2
Stratigraphy, 7
Subglacial drainage, 19
Surface, 3, 4, 7
Surface wells, 25
Swamp, 1, 3, 13, 16, 18, 25, 26

T.

Tamarack, 1
Taylor, F. B., 2, 14, 15, 16, 17
Terraces, 15, 19
Tile, 24
Topography, 3, 4, 5
Topographical map, 5
Towns, 2
Traverse shale, 12
Tropidonotus, 2
Turkey (wild), 2
Tuscola county, 1, 3, 16
Tyre, 4, 12, 13, 15, 16, 22, 23
Tyre-Ubly channel, 16, 19

U.

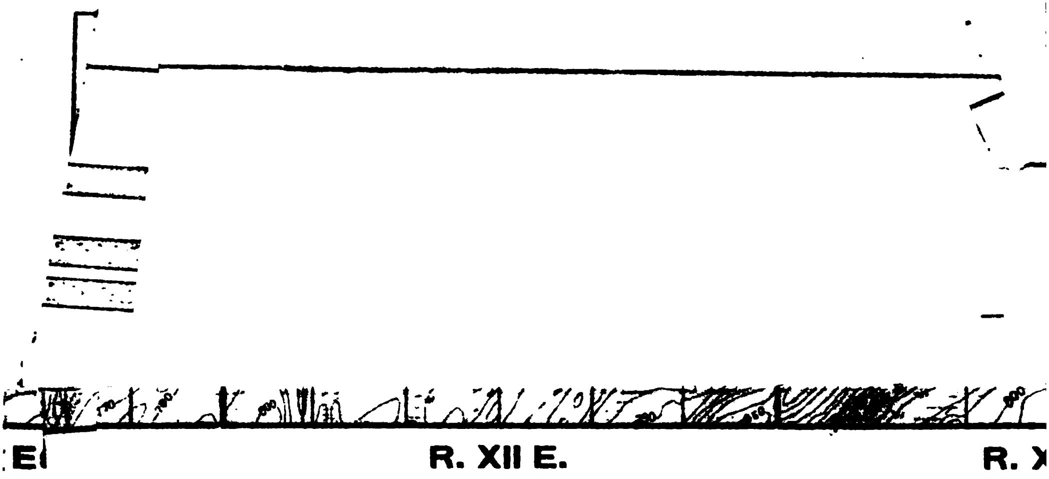
Ubly, 13, 15, 16
United States Geological Survey, 17
Union City, 22

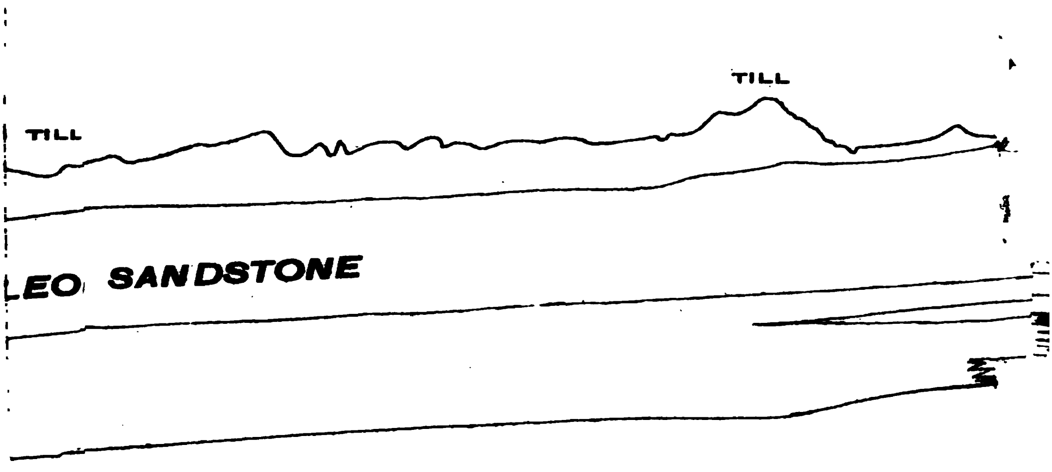
V.

Valley Center (well), 10, 11, 26, 27
Valley train deposits, 15
Vassar, 17
Vegetation, 1
Vegetable mold, 25

W.

Walled lakes of Iowa, 19
Walker, Bryant, 18
Washington Township (T. 11 N., R. 15 E.), 14, 24
Section 15, 24
Wells, 7, 9, 10, 11, 21, 25, 26
Water supplies, 25
Weber & Abner's brickyard, 16, 23
Wheat, 1
White, Mr., 20
White pine, 1
White Rock, 9, 22
Whortleberries, 1
Wolf, 2
Worth Township, 5, 17





OLOGICAL CROSS SECTION ALONG THE SOUTH LINE OF HURON

GEOLOGICAL SURVEY OF MICHIGAN.

SURFACE GEOLOGY
(PLEISTOCENE)

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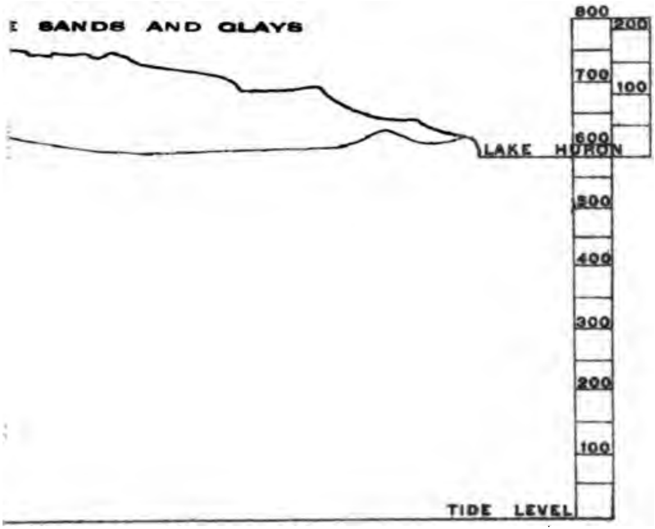

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